

Atlas of Anatomy

Fourth Edition

Edited by
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Brian R. MacPherson
Jamie C. Wikenheiser

Based on the work of
Michael Schuenke
Erik Schulte
Udo Schumacher

Illustrations by
Markus Voll
Karl Wesker



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Fourth Edition

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2113 illustrations

Thieme

New York · Stuttgart · Delhi · Rio de Janeiro

Illustrators: Markus Voll and Karl Wesker
Development Editor: Judith Tomat
Production Editor: Barbara Chernow
Compositor: Carol Pierson, Chernow Editorial Services, Inc.

Library of Congress Cataloging-in-Publication Data

Names: Gilroy, Anne M., editor. | MacPherson, Brian R., editor. | Wikenheiser, Jamie C., editor. | Voll, Markus M., illustrator. | Wesker, Karl, illustrator. | Schünke, Michael. Thieme atlas of anatomy.
Title: Atlas of anatomy / edited by Anne M. Gilroy, Brian R. MacPherson, Jamie C. Wikenheiser ; based on the work of Michael Schuenke, Erik Schulte, Udo Schumacher ; illustrations by Markus Voll, Karl Wesker.
Other titles: Atlas of anatomy (Gilroy)
Description: Fourth edition. | New York : Thieme, [2020] | Includes index. | Summary: "An updated atlas that provides a clear, accurate, and fully illustrated guide to human anatomy"— Provided by publisher.
Identifiers: LCCN 2019058797 (print) | LCCN 2019058798 (ebook) | ISBN 9781684202034 (paperback) | ISBN 9781684202041 (ebook)
Subjects: MESH: Anatomy | Atlas
Classification: LCC QM25 (print) | LCC QM25 (ebook) | NLM QS 17 | DDC 611.0022/3—dc23
LC record available at <https://lccn.loc.gov/2019058797>
LC ebook record available at <https://lccn.loc.gov/2019058798>

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Thieme Publishers New York
333 Seventh Avenue, New York, NY 10001 USA
+1 800 782 3488, customerservice@thieme.com

Thieme Publishers Stuttgart
Rüdigerstrasse 14, 70469 Stuttgart, Germany
+49 [0]711 8931 421, customerservice@thieme.de

Thieme Publishers Delhi
A-12, Second Floor, Sector-2, Noida-201301
Uttar Pradesh, India
+91 120 45 566 00, customerservice@thieme.in

Thieme Revinter Publicações Ltda.
Rua do Matoso, 170 – Tijuca
Rio de Janeiro RJ 20270-135 – Brasil
+55 21 2563-9702
www.thiemerevinter.com.br

Cover design: Thieme Publishing Group

Printed in India by Replika Press Pvt. Ltd.

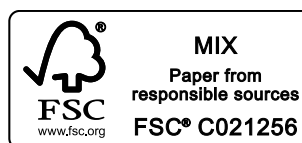
ISBN 978-1-68420-203-4

Also available as an e-book:
eISBN 978-1-68420-204-1

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Dedications

To the thousands of former students who have populated every specialty and migrated to every corner of this country, while dedicating their careers to making life better for thousands more. I am inspired by their empathy and kindness, and grateful to have been a small part of their journey.

And as always, to Colin and Bryan.

Anne M. Gilroy

To my friend and mentor Dr. Ken McFadden, who was responsible for my early training in gross anatomy and was a role model for success in teaching. I deeply appreciate the feedback I have received over the past 40 plus years from the thousands of students I have taught and who have made me an even better teacher. However, none of the success I have enjoyed in my life would have been possible without the constant support, assistance, and encouragement of my late wife, Cynthia Long.

Brian R. MacPherson

To my wife Jen and my son Quinn.

Jamie C. Wikenheiser

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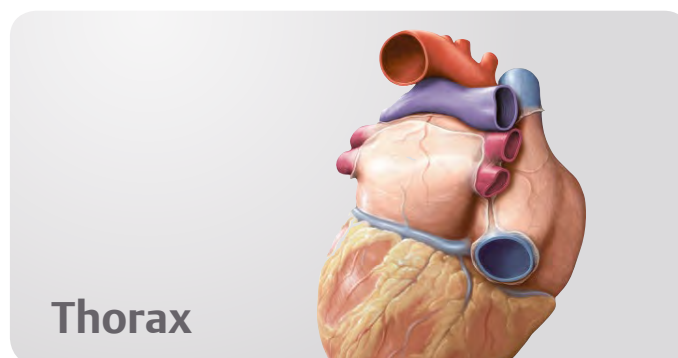
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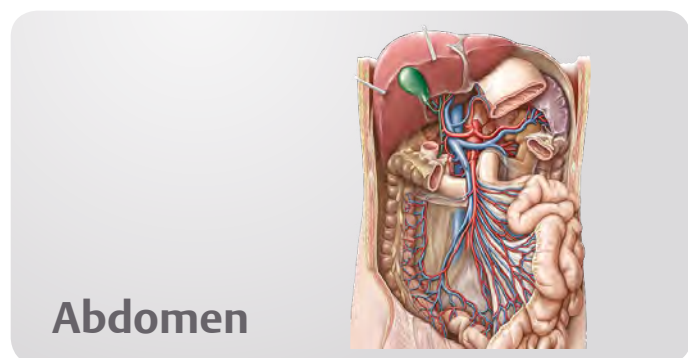
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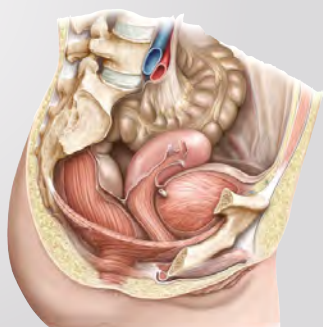
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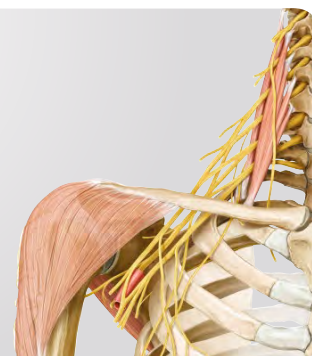
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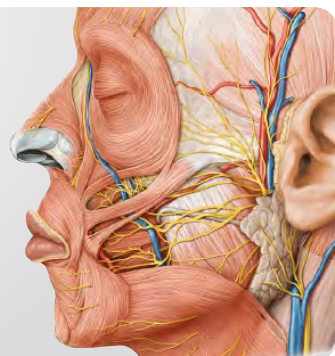
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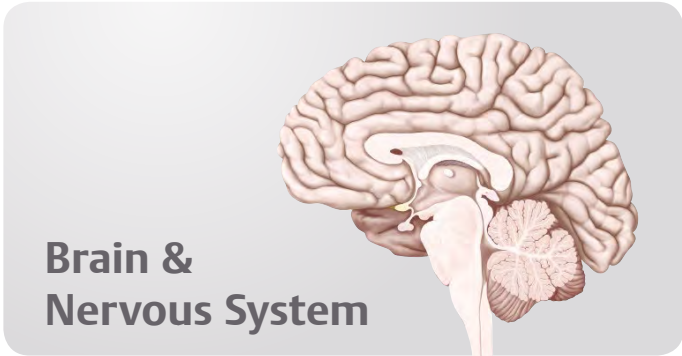
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Acknowledgments

We would like to thank the authors of the original award-winning *Thieme Atlas of Anatomy* three-volume series, Michael Schuenke, Erik Schulte, and Udo Schumacher, and the illustrators, Karl Wesker and Marcus Voll, for their work over the course of many years.

We thank the many instructors, students, and translators for our non-English versions, who have taken the time to point out to us what we have done well and brought to our attention errors, ambiguities, and new information, or have suggested how we could present a topic more effectively. This input, combined with our experience teaching with the *Atlas*, have guided our work on this edition.

We cordially thank the reviewers of the third edition, especially those who provided in-depth feedback:

- Jennifer Brueckner-Collins, PhD
University of Louisville School of Medicine
Louisville, Kentucky
- Jennifer Carr, PhD
Salem State University
Salem, Massachusetts
- C. Cem Denk, MD, PhD
Hacettepe University
Faculty of Medicine
Ankara, Turkey
- Gary J. Farkas, PhD
University of California, San Francisco School of Medicine
San Francisco, California
- Derek Harmon, PhD
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- Lindsey Kent (Class of 2020)
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The College of St. Scholastica
Duluth, Minnesota
- William J. Swartz, PhD
LSU Health Sciences Center
New Orleans, Louisiana

Foreword

This *Atlas of Anatomy*, in my opinion, is the finest single-volume atlas of human anatomy that has ever been created. Two factors make it so: the images and the way they have been organized.

The artists, Markus Voll and Karl Wesker, have created a new standard of excellence in anatomical art. Their graceful use of transparency and their sensitive representation of light and shadow give the reader an accurate three-dimensional understanding of every structure.

The authors have organized the images so that they give just the flow of information a student needs to build up a clear mental image of the human body. Each two-page spread is a self-contained lesson that unobtrusively shows the hand of an experienced and thoughtful teacher. I wish I could have held this book in my hands when I was a student; I envy any student who does so now.

Robert D. Acland, 1941–2016
Louisville, Kentucky

December 2015

Preface

In this new fourth edition of the *Atlas of Anatomy*, we are proud to offer what we believe is our best effort at presenting a clear and accurate story of human anatomy. A significant part of this effort is the addition of our newest co-author, Dr. Jamie C. Wikenheiser from the University of California, Irvine. Jamie's love of anatomy, attention to detail, and proud background in teaching excellence in anatomy at all student levels makes him a highly qualified addition to the editorship of the *Atlas* that will ensure its continued development.

As with previous editions, we have made every attempt to respond to the requests, comments, and critiques of our world-wide users. As always, we recognize that anatomy is a changing science. As concepts and terminology evolve, we feel a responsibility to pass this on and keep these aspects of the *Atlas* updated. Thus, our initial task for this edition was to update and further clarify the material already present in the *Atlas*. Among these modifications was a major revision of the many autonomic innervation wiring schematics. These are now uniformly designed to clearly differentiate between sympathetic and parasympathetic components and pre- and post-ganglionic fibers. We improved many tables by reorganizing and rewording the content and enlarging labels. Sectional and radiographic chapters in each unit, established in the third edition, have been expanded with more than forty additional MR and CT images, now accompanied, as are all sectional images throughout the *Atlas*, by new simplified navigators.

Another focus of this edition was to provide more written and schematic-based information that addresses complex anatomic concepts. This includes new schematics that complement other images, expanded legends that accompany images, and most notably, the addition of almost thirty new clinical boxes (most with illustrations) in every unit. These focus on function, pathology, anatomic variations, clinical procedures, diagnostic techniques, embryological development, and aging.

We continue to try to make difficult areas of anatomy more easily understood through better organization of chapter content and new diagrammatic approaches. The two-page spread that has been so popular in previous editions has been maintained in this edition, but an effort was made to improve their layouts by tabulating some content and adding more than 120 new illustrations and images. In this edition, the reader

will notice major changes in two regions. In the abdomen and pelvic units, a greater focus is placed on the peritoneum, mesenteries, and peritoneal spaces. The inguinal region, a difficult area for students, is also expanded with new images and tables, as well as new and revised images of perineal structures. The head and neck unit is the second area of major revisions. In an effort to bring this material into alignment with the way it is usually encountered in the dissection lab, the chapter on the neck now precedes those on the head and includes new artwork that promotes the dissection views. Students will appreciate the reorganization and additional clarifying images of areas such as the cavernous sinus, pterygopalatine and infratemporal fossae, and oral and nasal cavities. Finally, a new expanded overview introduces the brain and nervous system chapter.

As always, we are extremely grateful for the contributions of the many colleagues and reviewers who provide important feedback on earlier editions, alert us to inaccuracies and ambiguities, and share suggestions for new material.

We recognize that our efforts, though important, are just one part of the process that brings this textbook to its final production. The entire Thieme Publishers team has encouraged and supported our efforts throughout this process. Our deep appreciation is extended to the most important contributors: Judith Tomat, Developmental Editor; Delia DeTurris, Acquisitions Editor, and Barbara Chernow, PhD, Production Manager, for their dedication and expertise in their respective fields and their confidence in our ability to produce a quality manuscript.

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December 2019

Preface to the First Edition

Each of the authors was amazed and impressed with the extraordinary detail, accuracy, and beauty of the illustrations that were created for the *Thieme Atlas of Anatomy*. We feel these images are one of the most significant additions to anatomical education in the past 50 years. It was our intent to use these exceptional illustrations as the cornerstone of our effort in creating a concise single volume *Atlas of Anatomy* for the curious and eager health science student.

Our challenge was first to select from this extensive collection those images that are most instructive and illustrative of current dissection approaches. Along the way, however, we realized that creating a single-volume atlas was much more than choosing images: each image has to convey a significant amount of detail while the appeal and labeling need to be clean and soothing to the eye. Therefore, hundreds of illustrations were drawn new or modified to fit the approach of this new atlas. In addition, key schematic diagrams and simplified summary-form tables were added wherever needed. Dozens of applicable radiographic images and important clinical correlates have been added where appropriate. Additionally, surface anatomy illustrations are accompanied by questions designed to direct the student's attention to anatomic detail that is most relevant in conducting the physical exam. Elements from each of these features are arranged in a regional format to facilitate common dissection approaches. Within each region, the various components are examined systemically, followed by topographical images to tie the systems together within the region. In all of this, a clinical perspective on the anatomical structures is taken. The unique two facing pages "spread" format focuses the user to the area/topic being explored.

We hope these efforts — the results of close to 100 combined years experience teaching the discipline of anatomy to bright, enthusiastic students — has resulted in a comprehensive, easy-to-use resource and reference.

We would like to thank our colleagues at Thieme Publishers who so professionally facilitated this effort. We cannot thank enough Cathrin E. Schulz, MD, Editorial Director, Educational Products, who so graciously reminded us of deadlines, while always being available to "trouble shoot" problems. More importantly, she encouraged, helped, and complimented our efforts.

We also wish to extend very special thanks and appreciation to Bridget Queenan, Developmental Editor, who edited and developed the manuscript with an outstanding talent for visualization and intuitive flow of information. We are very grateful to her for catching many details along the way while always patiently responding to requests for artwork and labeling changes.

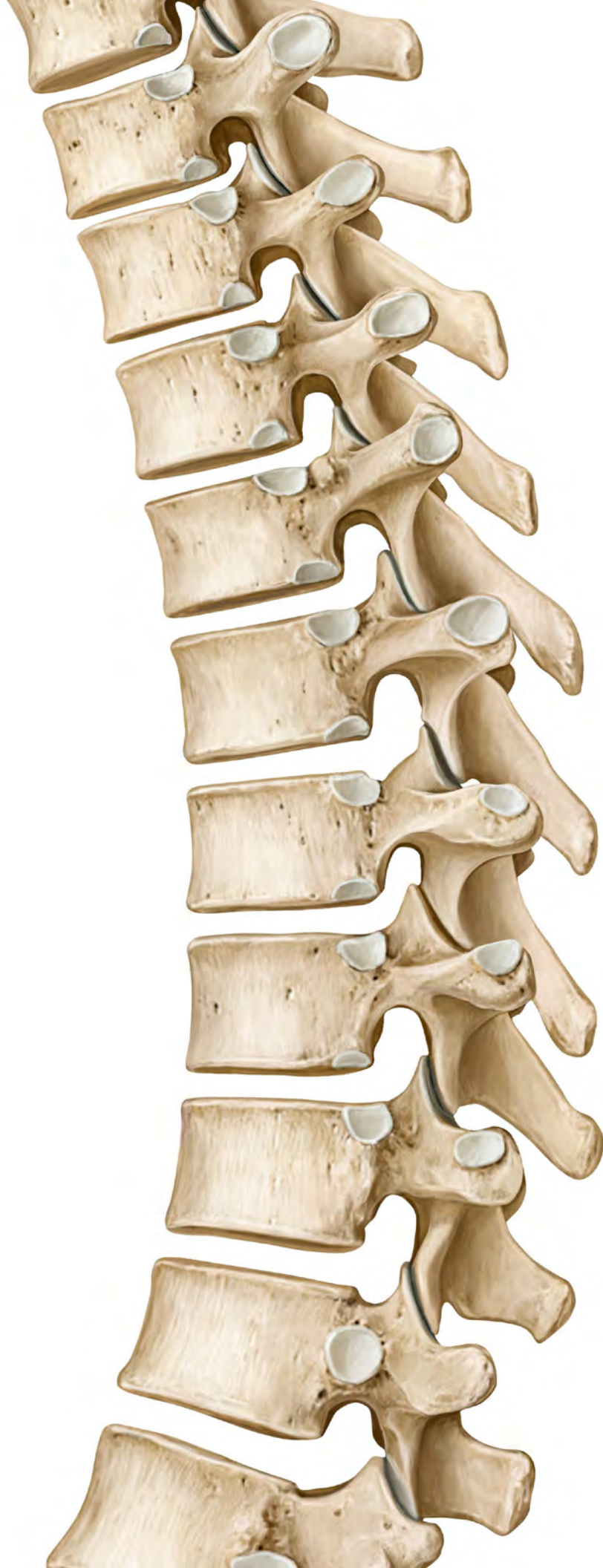
Cordial thanks to Elsie Starbecker, Senior Production Editor, who with great care and speed produced this atlas with its over 2,200 illustrations. Finally, thanks to Rebecca McTavish, Developmental Editor, for joining the team in the correction phase. So very much of their hard work has made the *Atlas of Anatomy* a reality.

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March 2008



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1 Surface Anatomy

Surface Anatomy

Fig. 1.1 Palpable structures of the back
Posterior view.

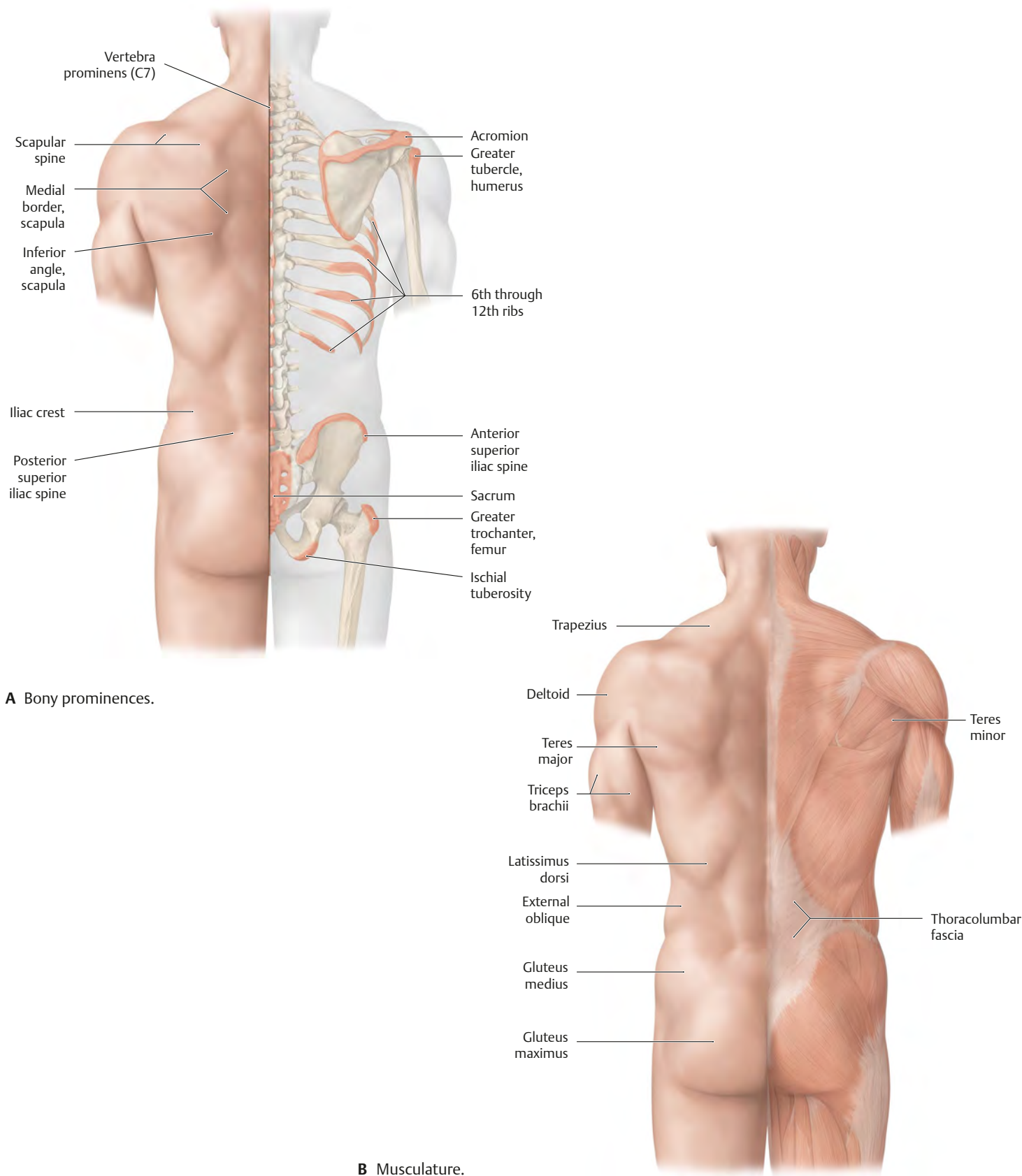
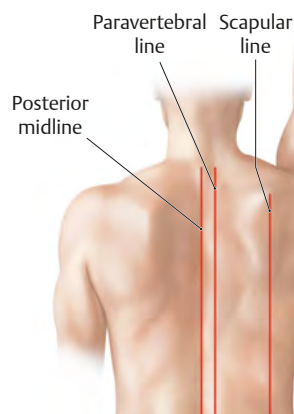
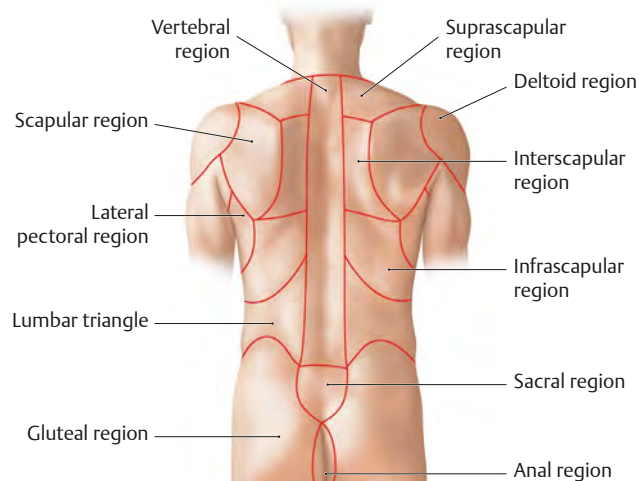


Fig. 1.2 Regions of the back and buttocks

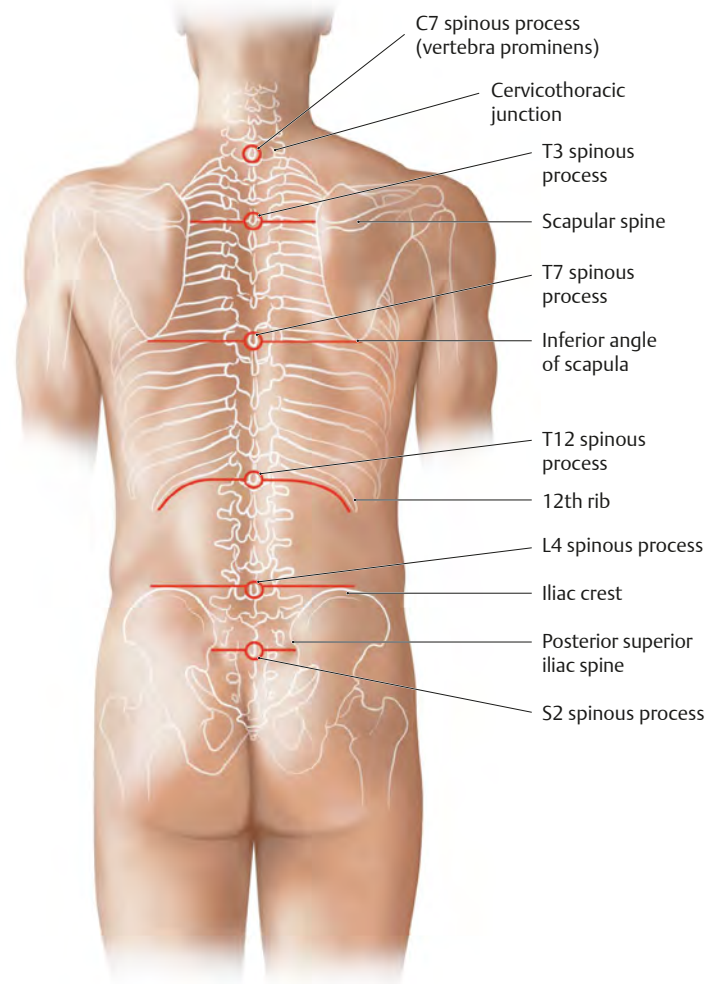
Posterior view.

**Table 1.1****Reference lines of the back**

Posterior midline	Posterior trunk midline at the level of the spinous processes
Paravertebral line	Line at the level of the transverse processes
Scapular line	Line through the inferior angle of the scapula

Fig. 1.3 Spinous processes and landmarks of the back

Posterior view.

**Table 1.2****Spinous processes that provide useful posterior landmarks**

Vertebral spinous process	Posterior landmark
C7	Vertebra prominens (the projecting spinous process of C7 is clearly visible and palpable)
T3	The scapular spine
T7	The inferior angle of the scapula
T12	Just below the 12th rib
L4	The summit of the iliac crest
S2	The posterior superior iliac spine (recognized by small skin depressions directly over the iliac spines)

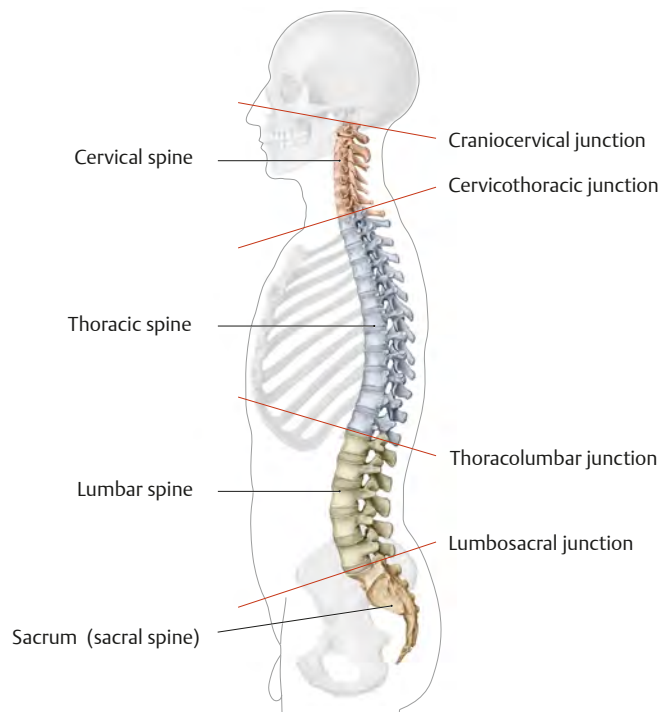
2 Bones, Ligaments & Joints

Vertebral Column: Overview

The vertebral column (spine) is divided into four regions: the cervical, thoracic, lumbar, and sacral spines. Both the cervical and lumbar spines

demonstrate lordosis (inward curvature); the thoracic and sacral spines demonstrate kyphosis (outward curvature).

Fig. 2.1 Vertebral column
Left lateral view.



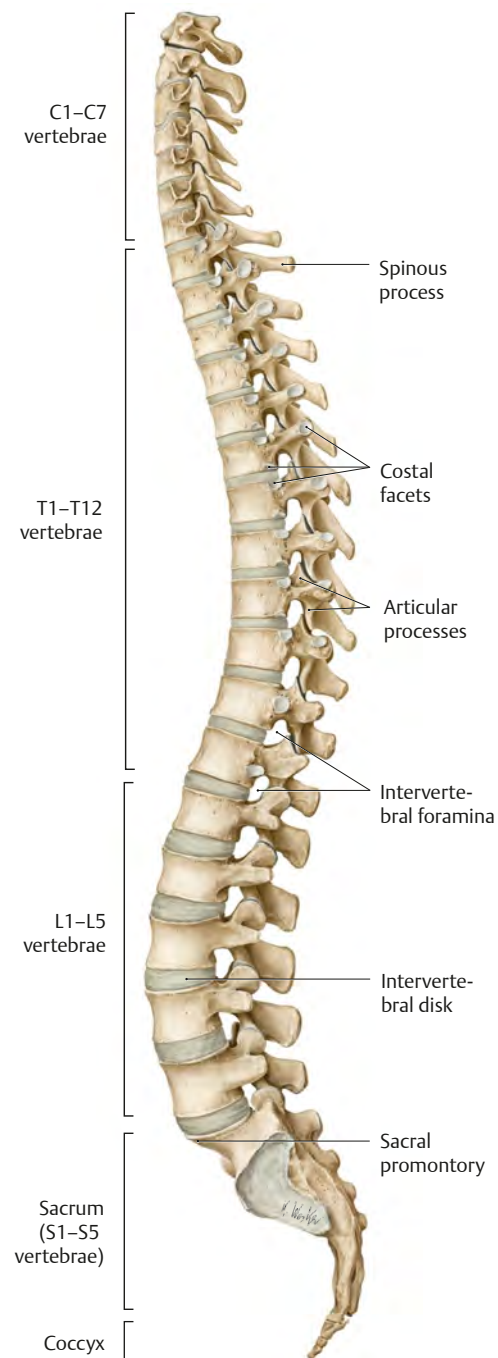
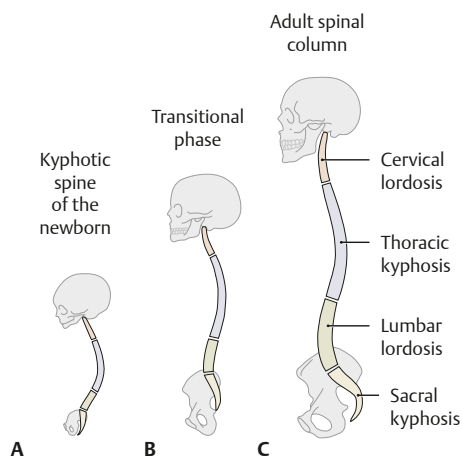
A Regions of the spine.



Clinical box 2.1

Spinal development

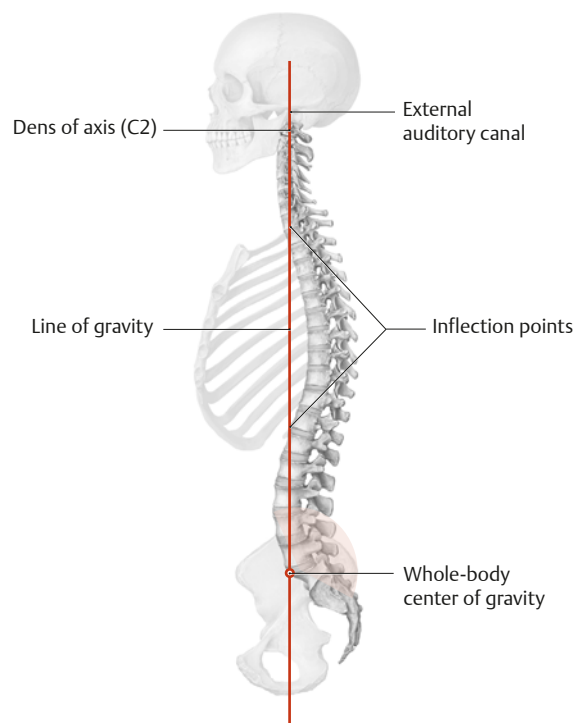
The characteristic curvatures of the adult spine appear over the course of postnatal development, being only partially present in a newborn. The newborn has a “kyphotic” spinal curvature (**A**); lumbar lordosis develops later and becomes stable at puberty (**C**).



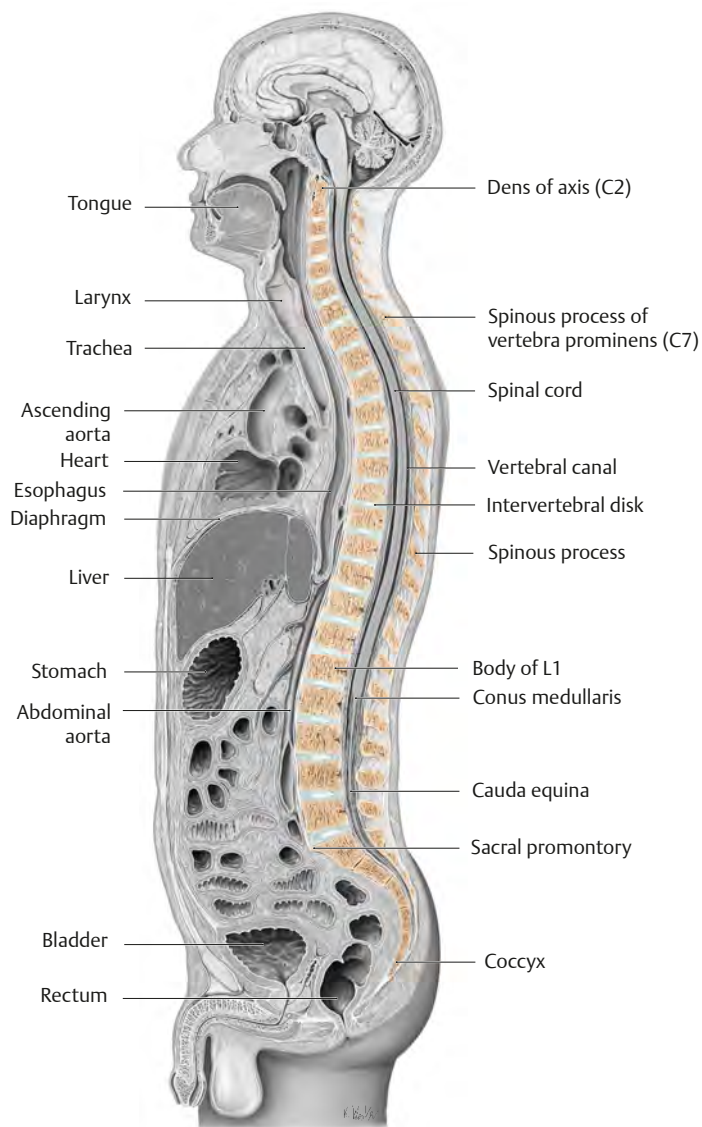
B Bony vertebral column.

Fig. 2.2 Normal anatomical position of the spine

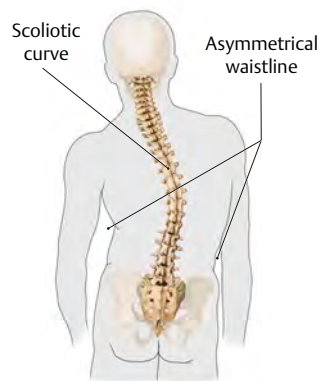
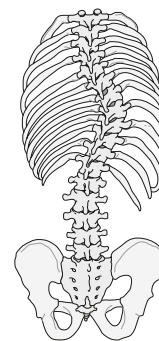
Left lateral view.



A Line of gravity. The line of gravity passes through certain anatomical landmarks, including the inflection points at the cervicothoracic and thoracolumbar junctions. It continues through the center of gravity (anterior to the sacral promontory) before passing through the hip joint, knee, and ankle.



B Midsagittal section through an adult male.

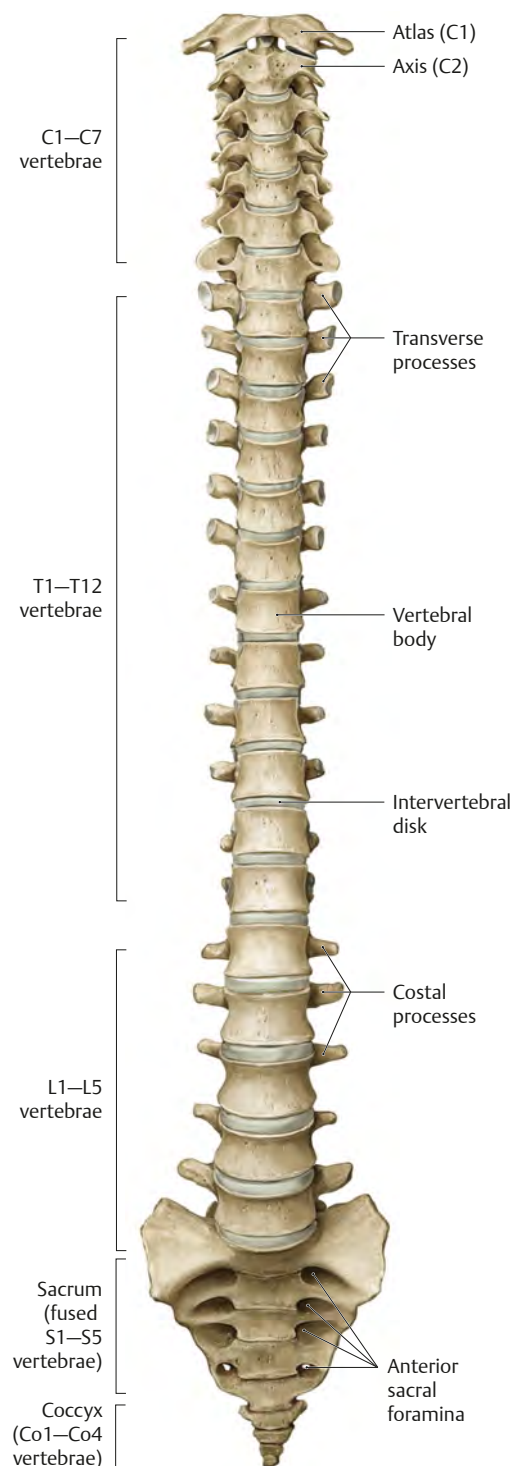
**Clinical box 2.2****Abnormal Vertebral Column Curvatures****A** Normal**B** Excessive kyphosis**C** Excessive lordosis**D** Scoliosis**E** Right convex thoracic scoliosis

Vertebral Column: Elements

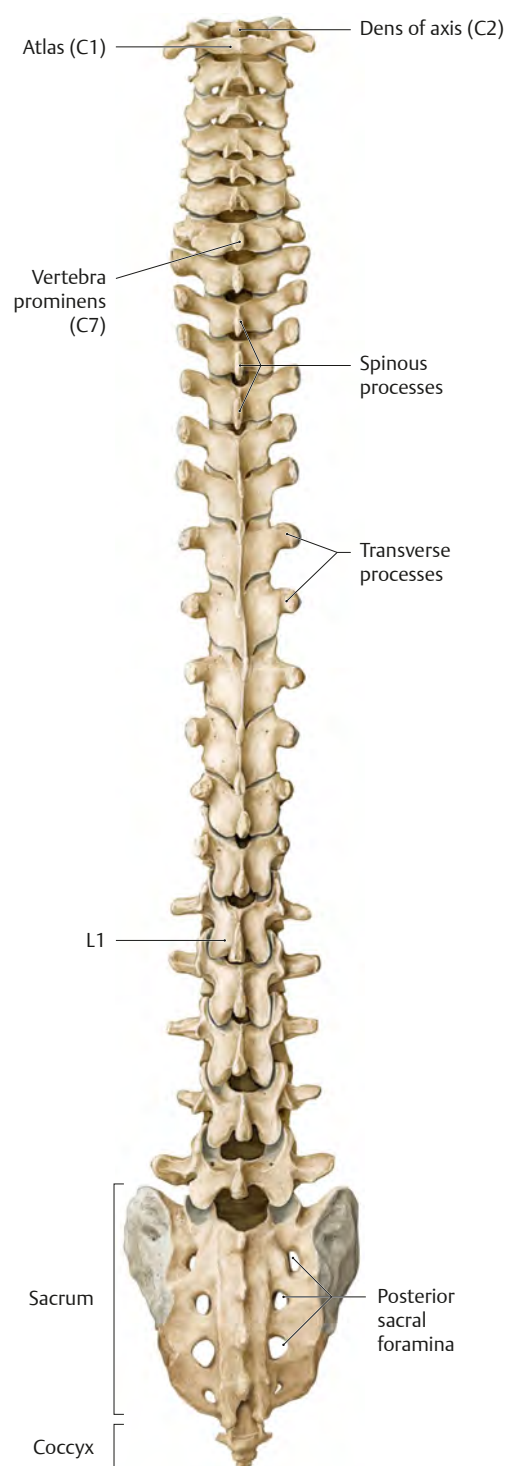
Back

Fig. 2.3 Bones of the vertebral column

The transverse processes of the lumbar vertebrae are originally rib rudiments and so are named costal processes.



A Anterior view.



B Posterior view.

Fig. 2.4 Structural elements of a vertebra

Left posterosuperior view. With the exception of the atlas (C1) and axis (C2), all vertebrae consist of the same structural elements.

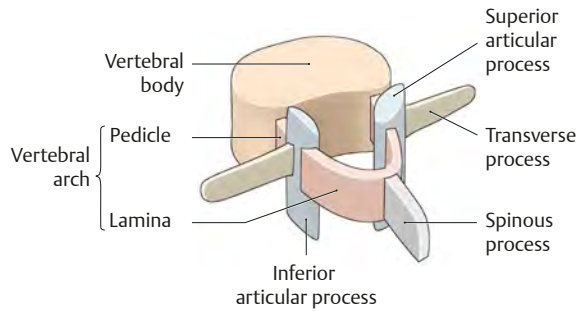
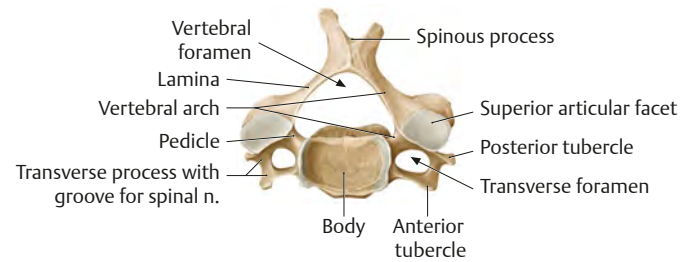
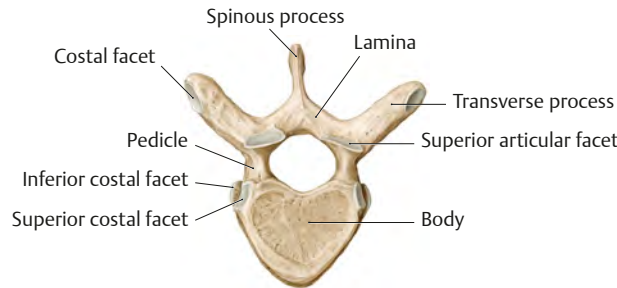


Fig. 2.5 Typical vertebrae

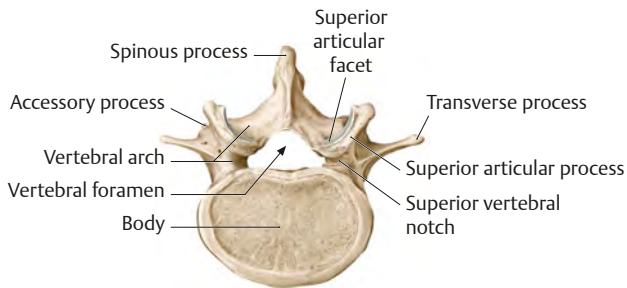
Superior view.



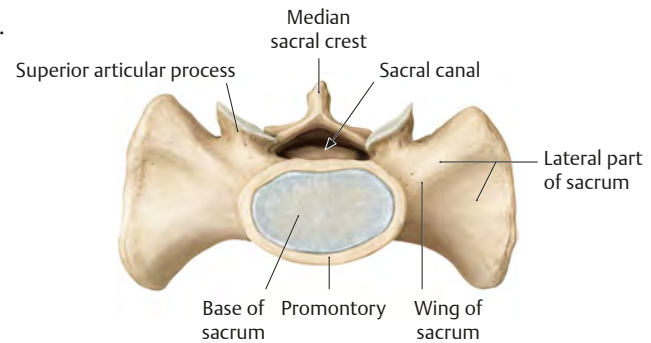
A Cervical vertebra (C4).



B Thoracic vertebra (T6).



C Lumbar vertebra (L4).



D Sacrum.

Table 2.1

Structural elements of vertebrae

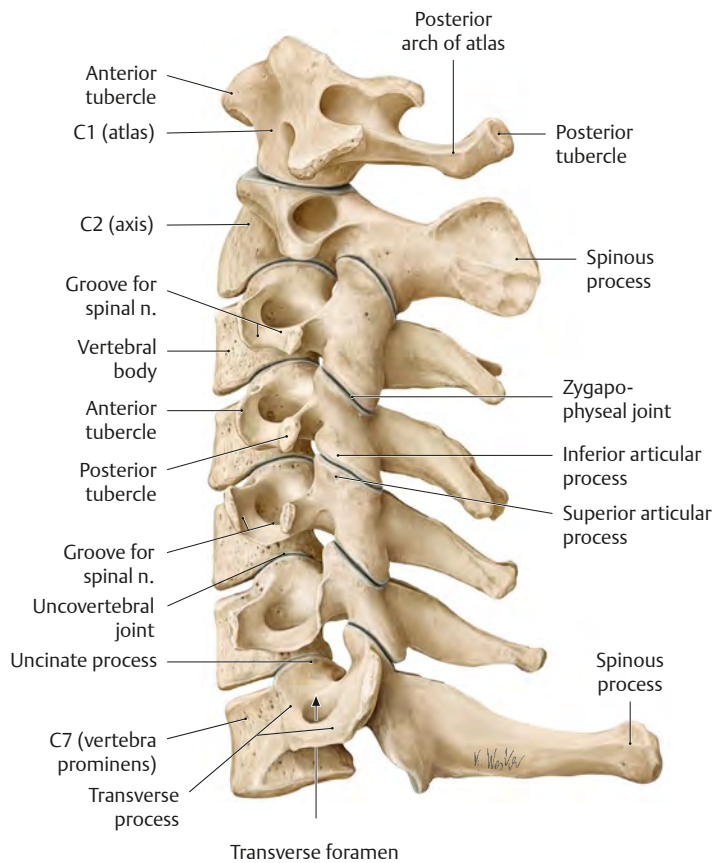
Vertebrae	Body	Vertebral foramen	Transverse processes	Articular processes	Spinous process
Cervical vertebrae C3*–C7	Small (kidney-shaped)	Large (triangular)	Small (may be absent on C7); anterior and posterior tubercles enclose transverse foramen	Superoposteriorly and inferoanteriorly; oblique facets; most nearly horizontal	Short (C3–C5); bifid (C3–C6); long (C7)
Thoracic vertebrae T1–T12	Medium (heart-shaped); includes costal facets	Small (circular)	Large and strong; length decreases T1–T12; costal facets (T1–T10)	Posteriorly (slightly laterally) and anteriorly (slightly medially); facets in coronal plane	Long, sloping postero-inferiorly; tip extends to level of vertebral body below
Lumbar vertebrae L1–L5	Large (kidney-shaped)	Medium (triangular)	Called costal processes, long and slender; accessory process on posterior surface	Posteromedially (or medially) and anterolaterally (or laterally); facets nearly in sagittal plane; mammillary process on posterior surface of each superior articular process	Short and broad
Sacral vertebrae (sacrum) S1–S5 (fused)	Decreases from base to apex	Sacral canal	Fused to rudimentary rib (ribs, see pp. 56–59)	Superoposteriorly (S1) superior surface of lateral sacrum-audicular surface	Median sacral crest

*C1 (atlas) and C2 (axis) are considered atypical (see pp. 8–9).

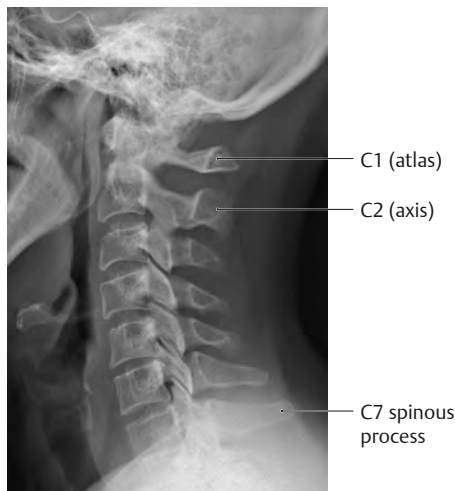
Cervical Vertebrae

The seven vertebrae of the cervical spine differ most conspicuously from the common vertebral morphology. They are specialized to bear the weight of the head and allow the neck to move in all directions.

Fig. 2.6 Cervical spine
Left lateral view.



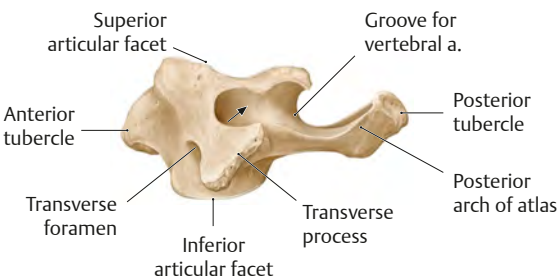
A Bones of the cervical spine, left lateral view.



B Radiograph of the cervical spine, left lateral view.

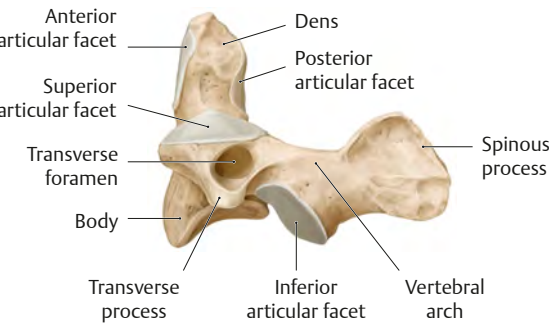
C1 and C2 are known as the atlas and axis, respectively. C7 is called the vertebra prominens for its long, palpable spinous process.

Fig. 2.7 Atlas (C1)



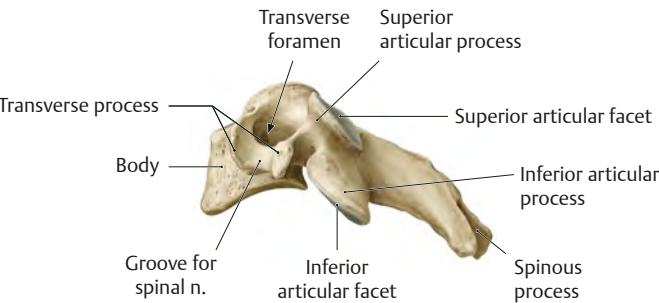
A Left lateral view.

Fig. 2.8 Axis (C2)



A Left lateral view.

Fig. 2.9 Typical cervical vertebra (C4)



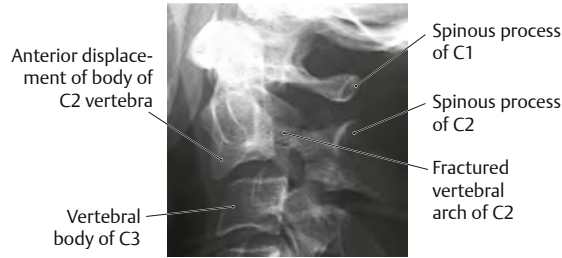
A Left lateral view.



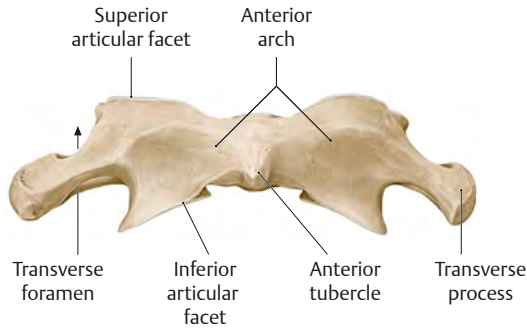
Clinical box 2.3

Injuries in the cervical spine

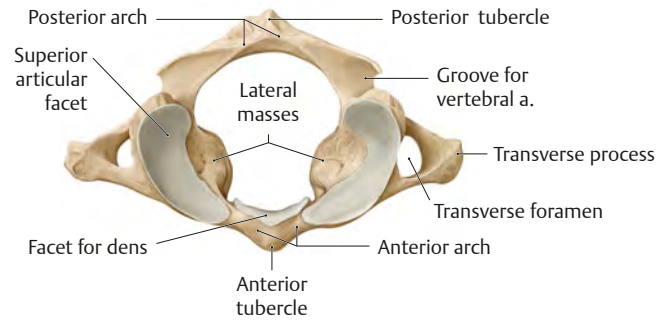
The cervical spine is prone to hyperextension injuries, such as “whiplash,” which can occur when the head extends back much farther than it normally would. The most common injuries of the cervical spine are fractures of the dens of the axis, traumatic spondylolisthesis (anterior slippage of a vertebral body), and atlas fractures. Patient prognosis is largely dependent on the spinal level of the injuries (see p. 42).



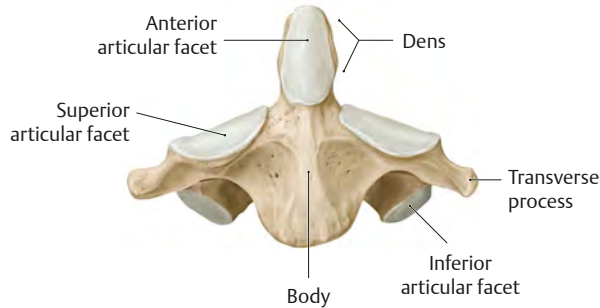
This patient hit the dashboard of his car while not wearing a seat belt. The resulting hyperextension caused the traumatic spondylolisthesis of C2 (axis) with fracture of the vertebral arch of C2, as well as tearing of the ligaments between C2 and C3. This injury is often referred to as “hangman’s fracture.”



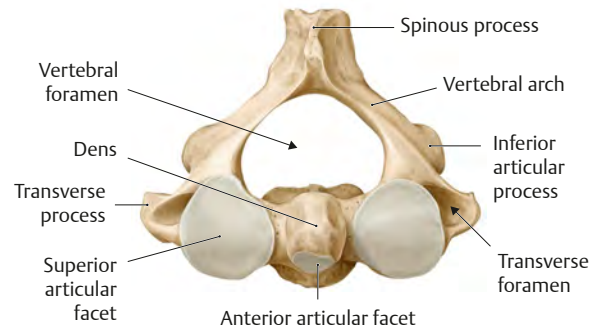
B Anterior view.



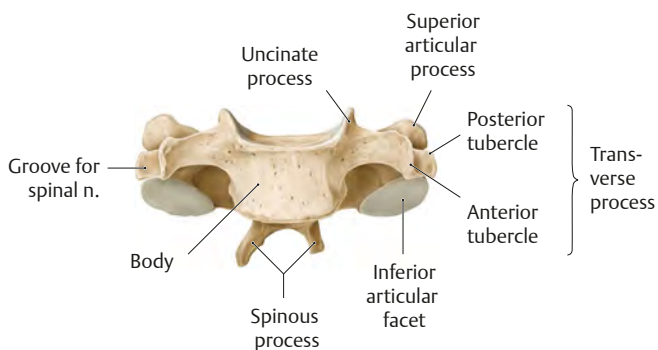
C Superior view.



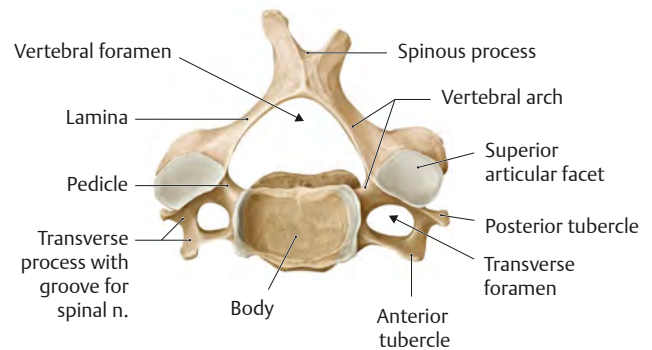
B Anterior view.



C Superior view.



B Anterior view.



C Superior view.

Fig. 2.10 Thoracic spine
Left lateral view.

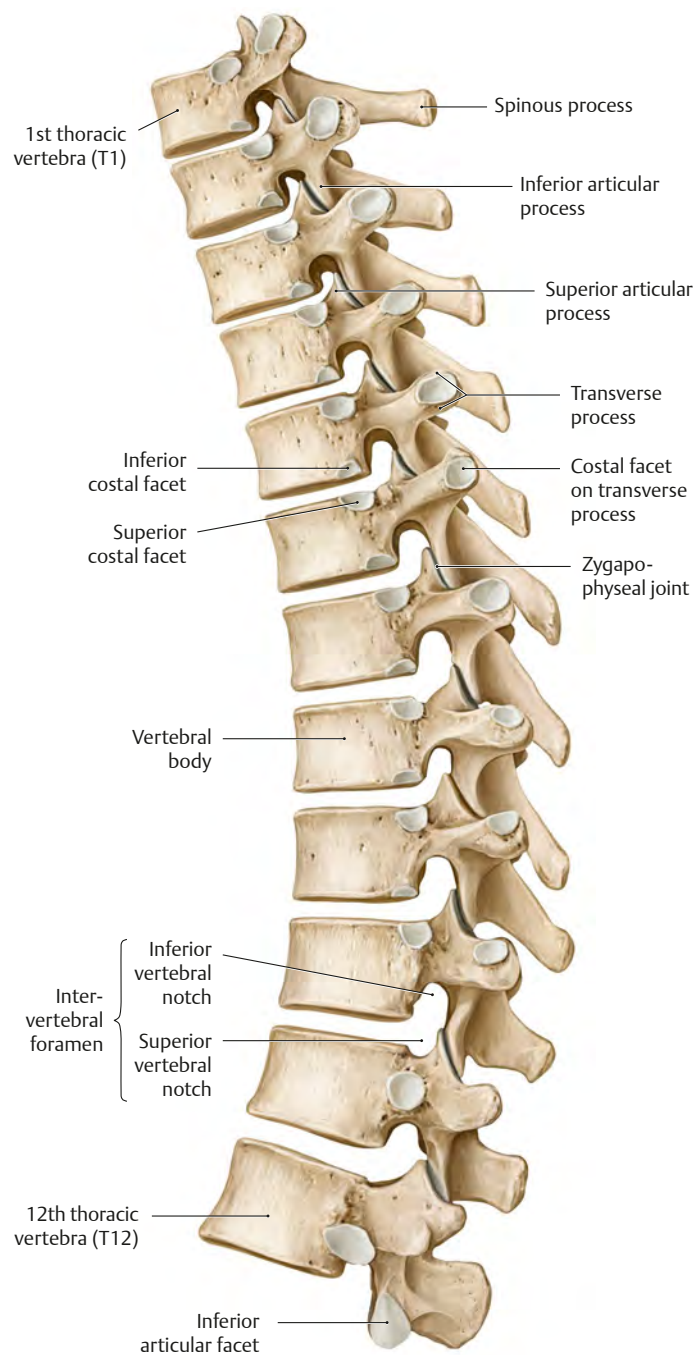
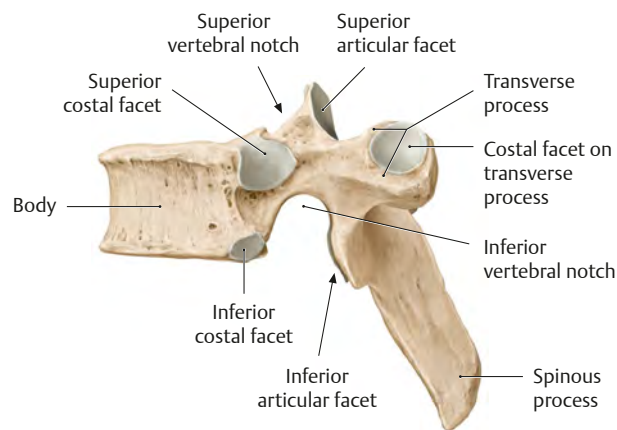
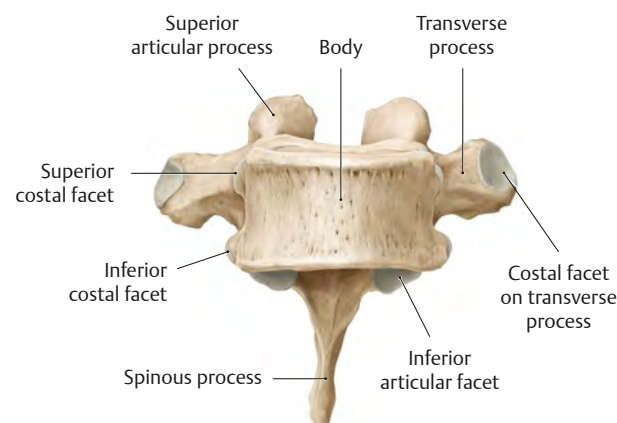


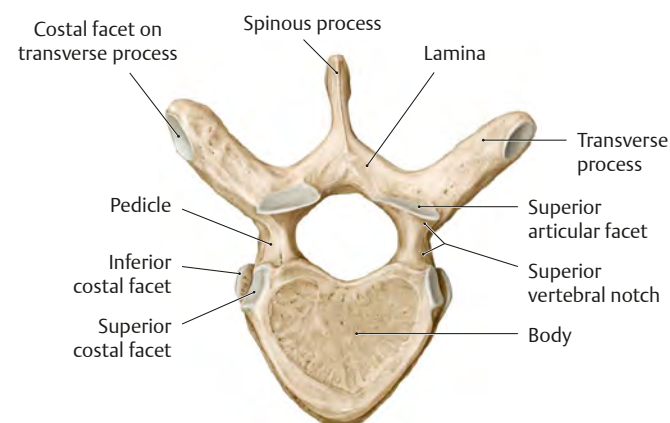
Fig. 2.11 Typical thoracic vertebra (T6)



A Left lateral view.



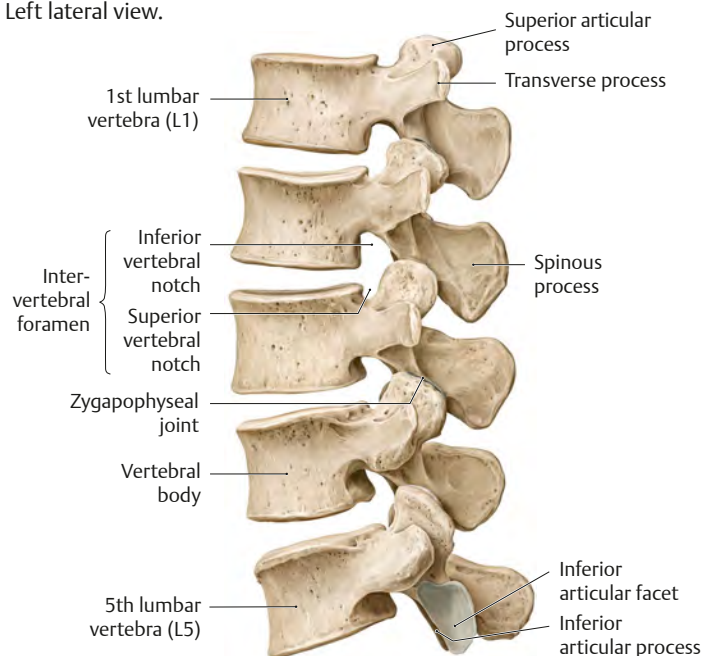
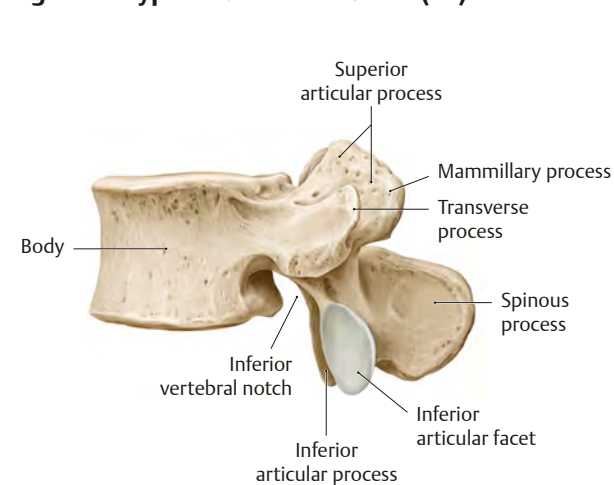
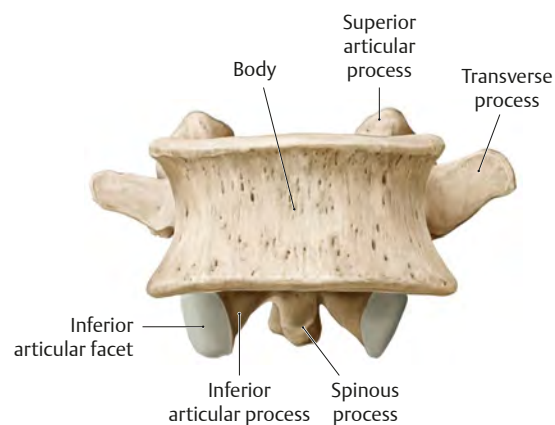
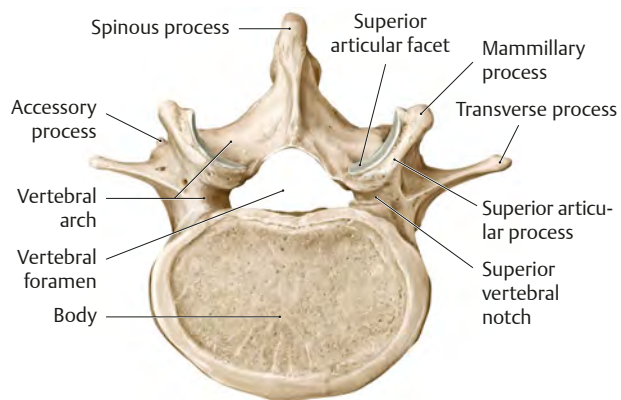
B Anterior view.



C Superior view.

Fig. 2.12 Lumbar spine

Left lateral view.

**Fig. 2.13 Typical lumbar vertebra (L4)****A** Left lateral view.**B** Anterior view.**C** Superior view.**Clinical box 2.4****Osteoporosis**

The spine is the structure most affected by degenerative diseases of the skeleton, such as arthrosis and osteoporosis. In osteoporosis, more bone material gets reabsorbed than built up, resulting in a loss of bone mass. Symptoms include compression fractures and resulting back pain.



A Radiograph of a normal lumbar spine, left lateral view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)



B Radiograph of an osteoporotic lumbar spine with a compression fracture at L1 (arrow). Note that the vertebral bodies are decreased in density, and the internal trabecular structure is coarse. (Reproduced from Jallo J, Vaccaro AR. Neurotrauma and Critical Care of the Spine, 1st ed. New York, NY: Thieme; 2009.)

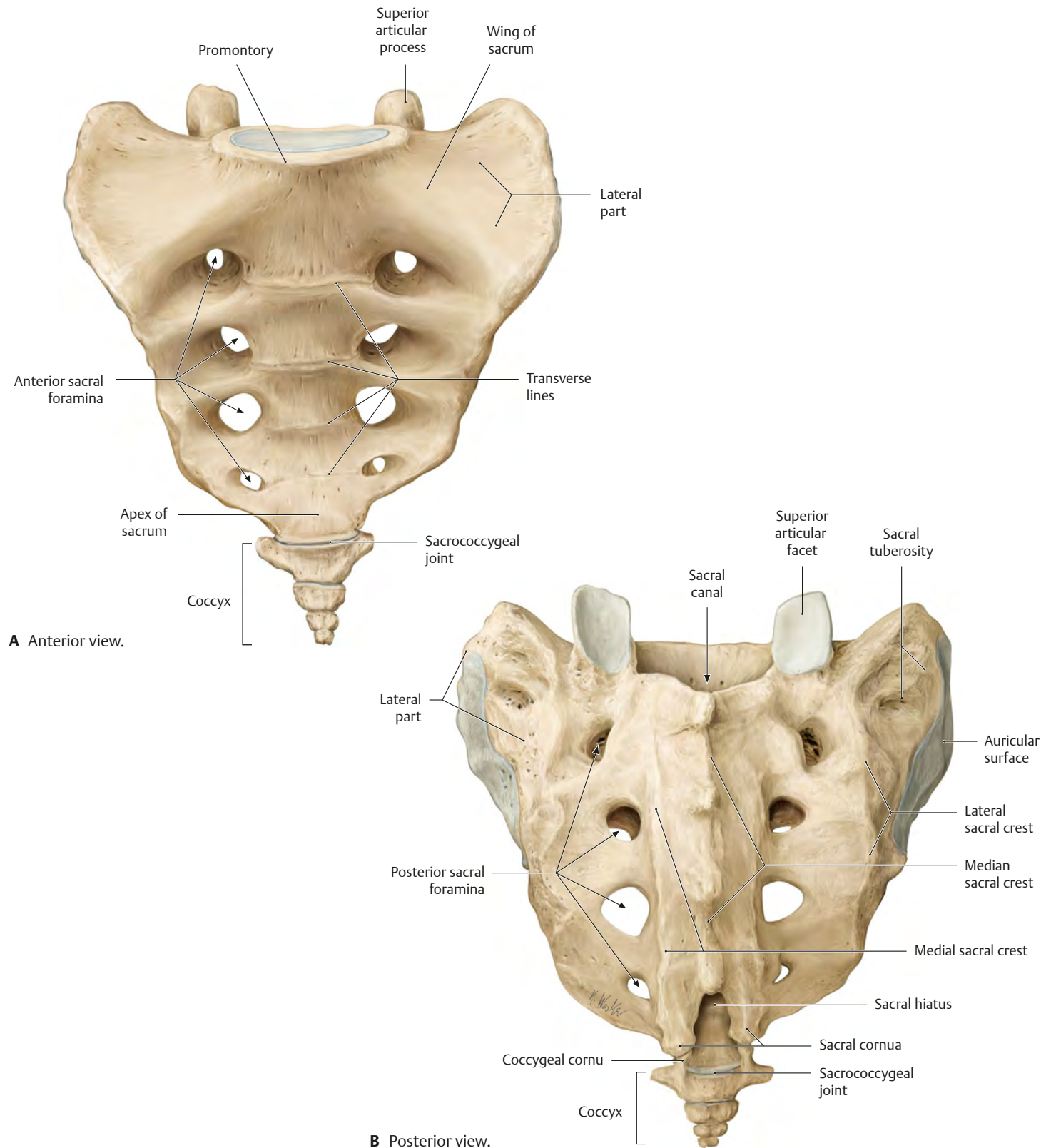
Sacrum & Coccyx

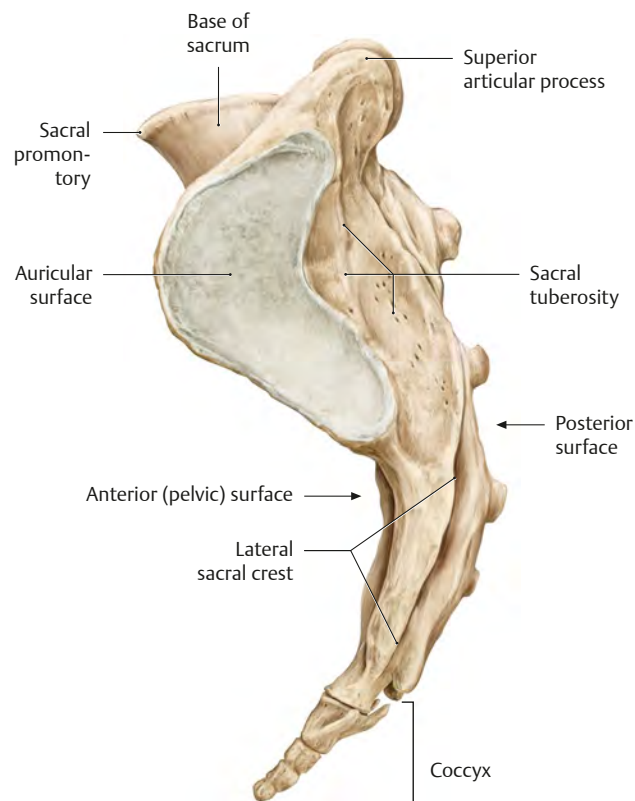
Back

The sacrum is formed from five postnatally fused sacral vertebrae. The base of the sacrum articulates with the 5th lumbar vertebra, and

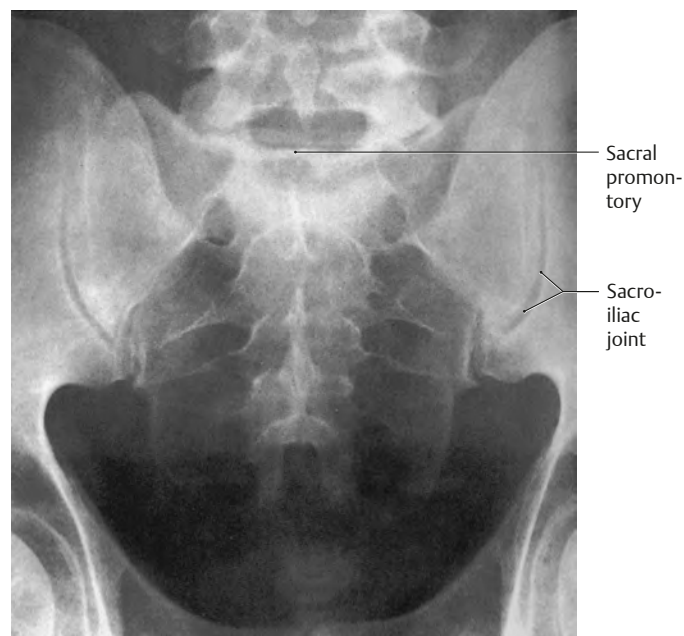
the apex articulates with the coccyx, a series of three or four rudimentary vertebrae. See **Fig. 19.1, p. 230.**

Fig. 2.14 Sacrum and coccyx



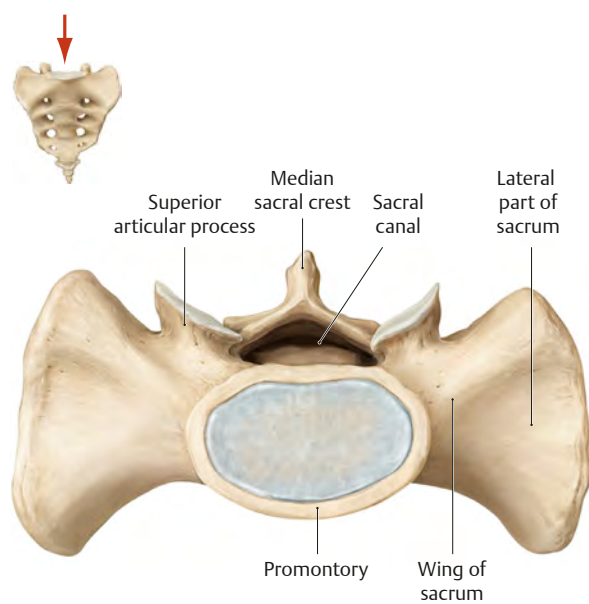


C Left lateral view.

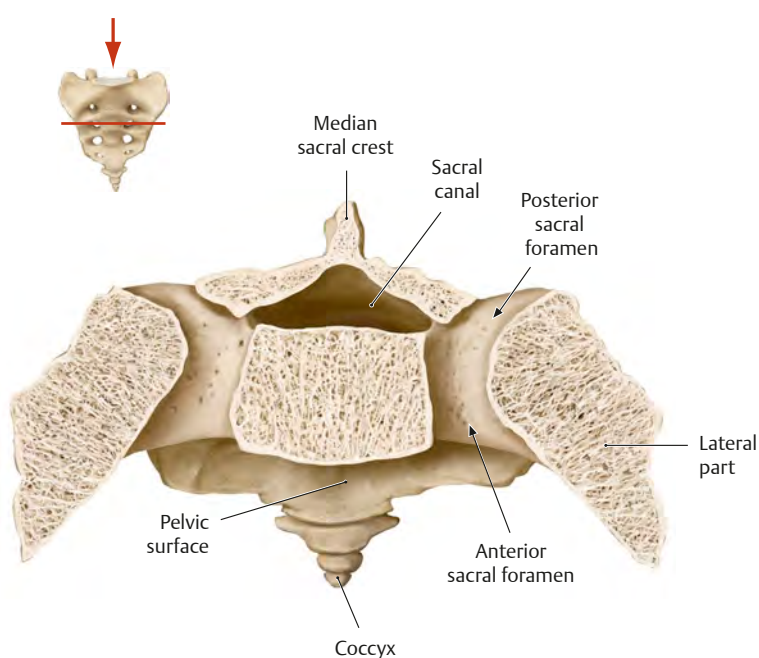


D Radiograph of sacrum, anteroposterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

Fig. 2.15 Sacrum
Superior view.



A Base of sacrum, superior view.



B Transverse section through second sacral vertebra demonstrating anterior and posterior sacral foramina, superior view.

Intervertebral Disks

Back

Fig. 2.16 Intervertebral disk in the vertebral column

Midsagittal section of T11–T12, left lateral view. The intervertebral disks occupy the spaces between vertebrae (intervertebral joints, see p. 16).

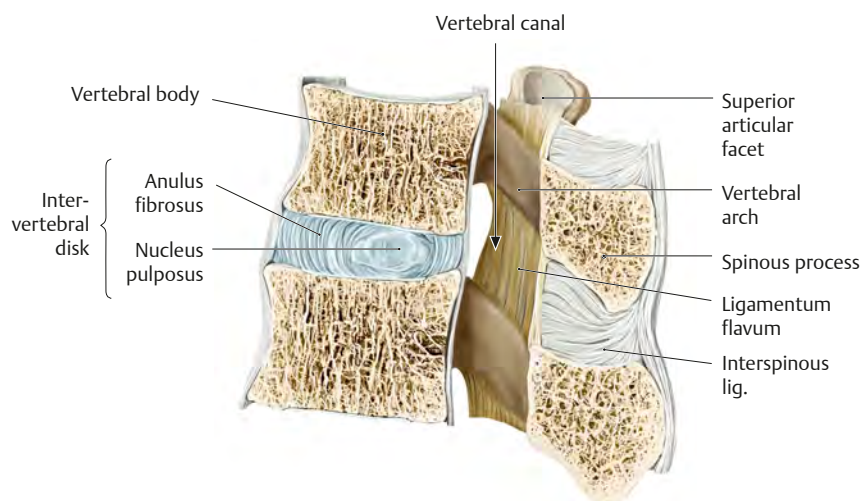


Fig. 2.17 Structure of intervertebral disk

Anterosuperior view with the anterior half of the disk and the right half of the end plate removed. The intervertebral disk consists of an external fibrous ring (anulus fibrosus) and a gelatinous core (nucleus pulposus).

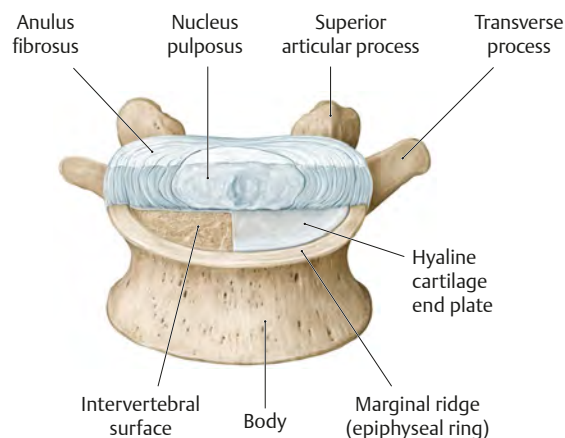


Fig. 2.18 Relation of intervertebral disk to vertebral canal

Fourth lumbar vertebra, superior view.

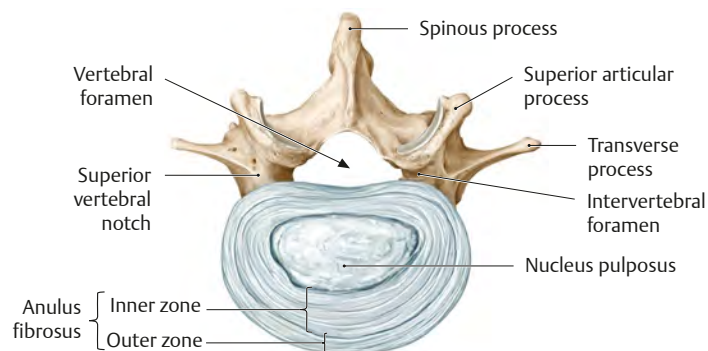
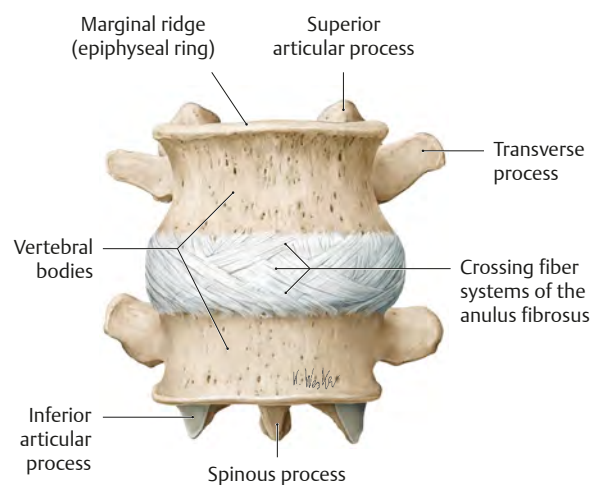


Fig. 2.19 Outer zone of the annulus fibrosus

Anterior view of L3–L4 with intervertebral disk.



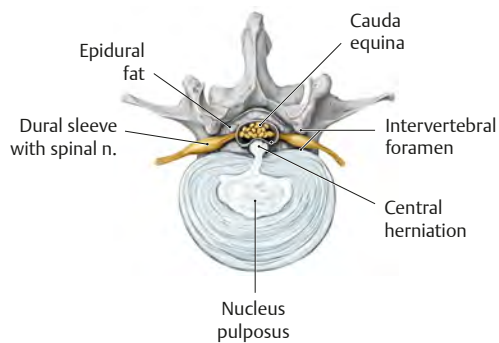


Clinical box 2.5

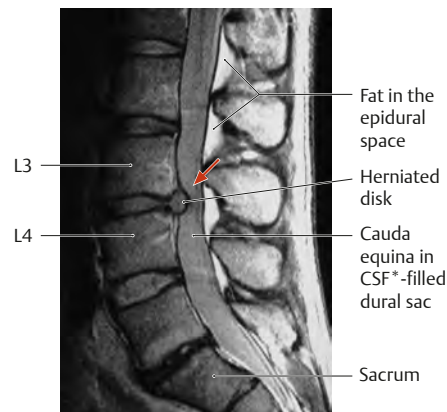
Disk herniation in the lumbar spine

As the stress resistance of the anulus fibrosus declines with age, the tissue of the nucleus pulposus may protrude through weak spots under loading. If the fibrous ring of the anulus ruptures completely, the herniated material may compress the contents of the intervertebral foramen (nerve roots and blood vessels—see posterolateral herniation below). These patients often suffer from severe local back pain. Pain is also felt in the associated dermatome

(see p. 42). When the motor part of the spinal nerve is affected, the muscles served by that spinal nerve will show weakening. It is an important diagnostic step to test the muscles innervated by a nerve from a certain spinal segment, as well as the sensitivity in the specific dermatome. Example: The first sacral nerve root innervates the gastrocnemius and soleus muscles; thus, standing or walking on toes can be affected (see p. 446).



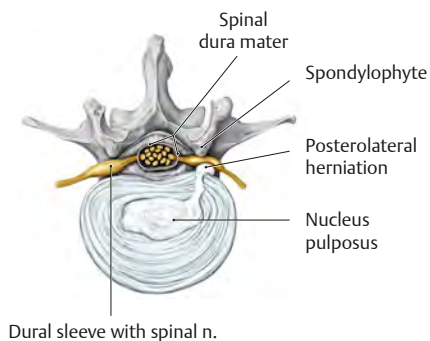
A Superior view.



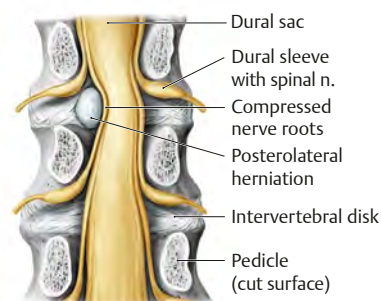
B Midsagittal T2-weighted MRI (magnetic resonance image).

Posterior herniation (A, B) In the MRI, a conspicuously herniated disk at the level of L3–L4 protrudes posteriorly (transligamentous herniation). The dural

sac is deeply indented at that level. *CSF (cerebrospinal fluid).



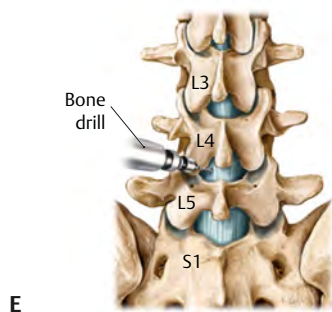
C Superior view.



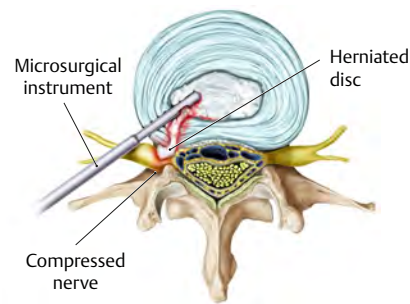
D Posterior view, vertebral arches removed.

Posterolateral herniation (C, D) A posterolateral herniation may compress the spinal nerve as it passes through the intervertebral foramen. If more

medially positioned, the herniation may spare the nerve at that level but impact nerves at inferior levels.



E



F

Microdiscectomy surgery (**E, F**) is performed in order to remove a portion of a herniated disc that is irritating the nerve root. Through a small incision, the erector spinae muscles are reflected laterally to expose the ligamentum flavum, which is then removed in order to access the nerve roots in

the spinal canal. A small portion of the facet joint may be removed to both facilitate access and relieve pressure on the nerve roots. Only the herniated portion of the disk is removed with the remaining tissue left intact.

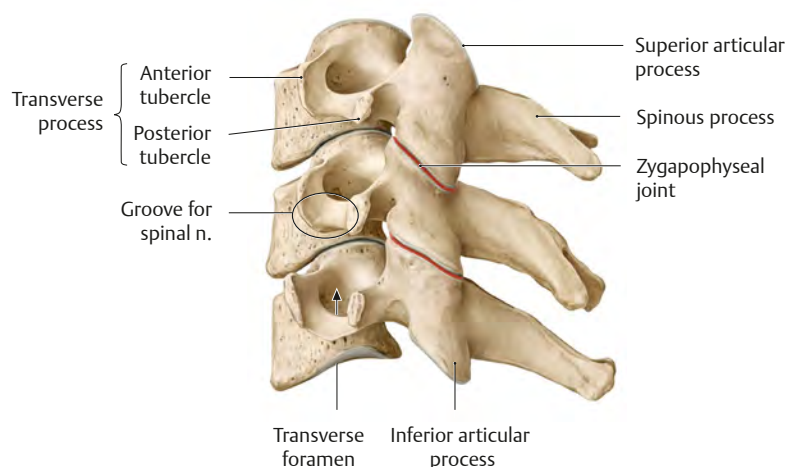
Joints of the Vertebral Column: Overview

Back

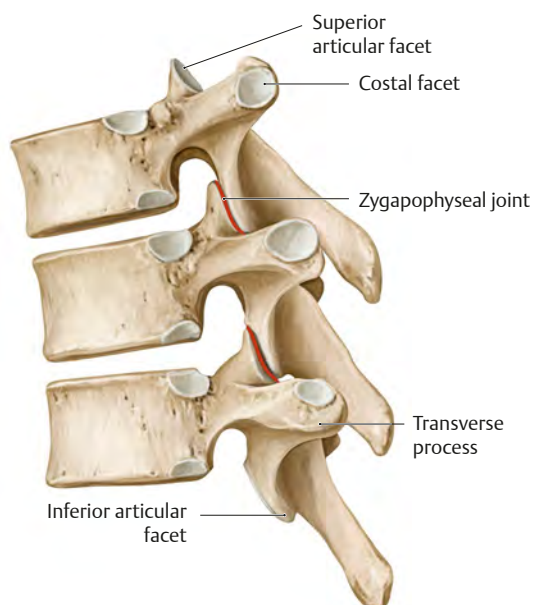
Table 2.2 Joints of the vertebral column		
Craniovertebral joints		
①	Atlanto-occipital joints	Occiput–C1
②	Atlantoaxial joints	C1–C2
Joints of the vertebral bodies		
③	Uncovertebral joints	C3–C7
④	Intervertebral joints	C2–S1
Joints of the vertebral arch		
⑤	Zygapophyseal joints	C2–S1

Fig. 2.20 Zygapophyseal (intervertebral facet) joints

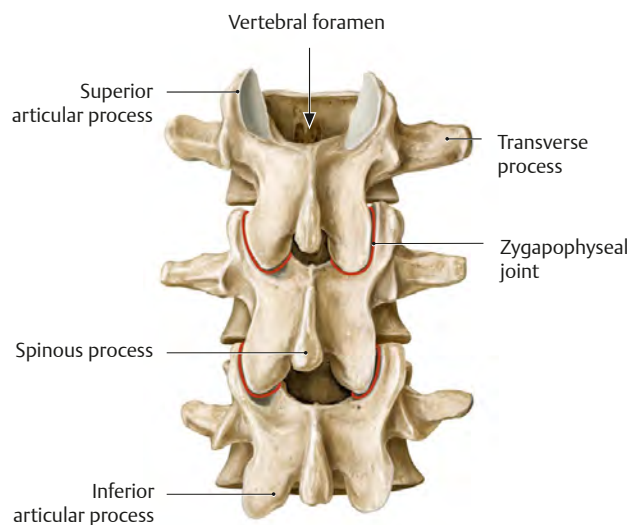
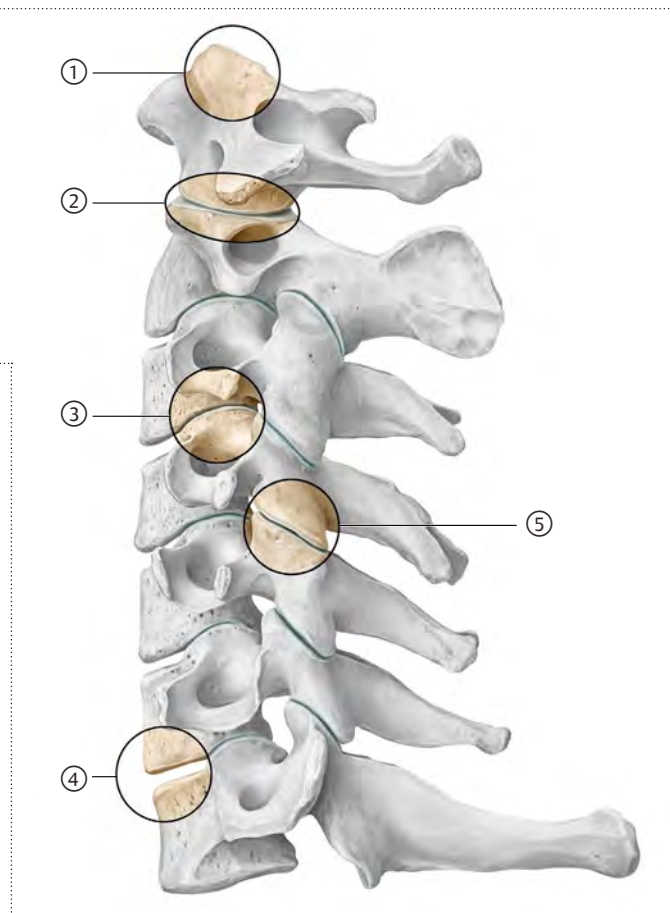
The orientation of the zygapophyseal joints differs between the spinal regions, influencing the degree and direction of movement.



A Cervical region, left lateral view. The zygapophyseal joints lie 45 degrees from the horizontal.



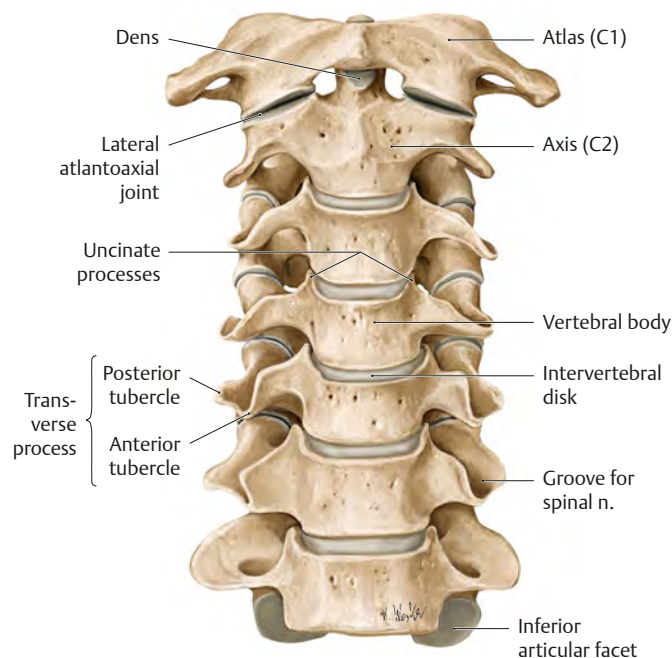
B Thoracic region, left lateral view. The joints lie in the coronal plane.



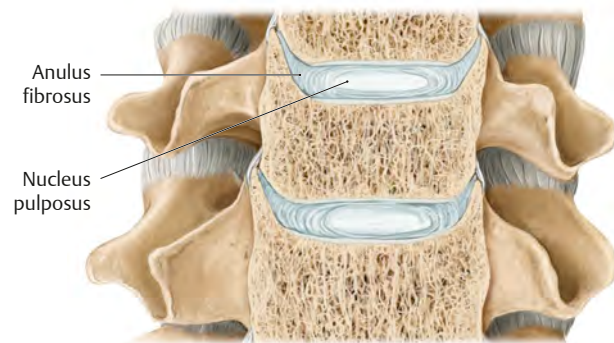
C Lumbar region, posterior view. The joints lie in the sagittal plane.

Fig. 2.21 Uncovertebral joints

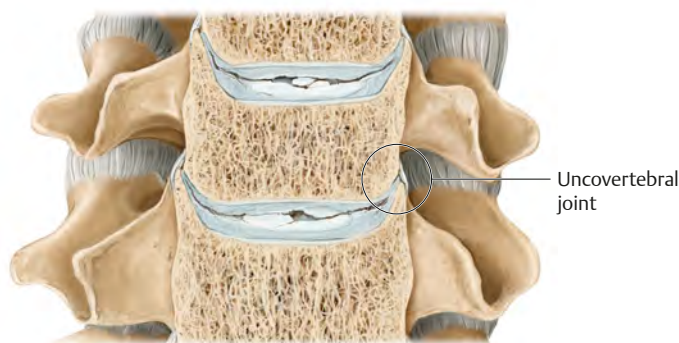
Anterior view. Uncovertebral joints form during childhood between the uncinate processes of C3–C7 and the vertebral bodies immediately superior. The joints may result from fissures in the cartilage of the disks that assume an articular character. If the fissures become complete tears, the risk of nucleus pulposus herniation is increased (see p. 15).



A Uncovertebral joints in the cervical spine of an 18-year-old man, anterior view.



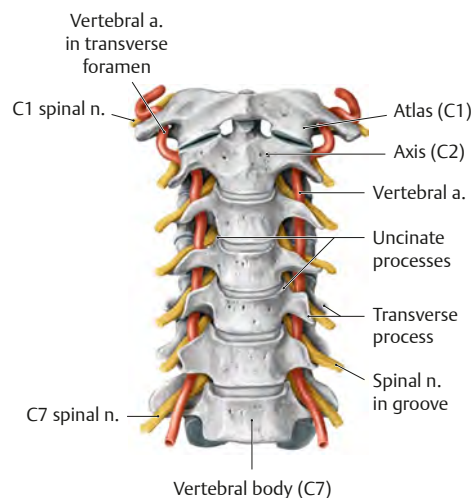
B Uncovertebral joint (enlarged), anterior view of coronal section.



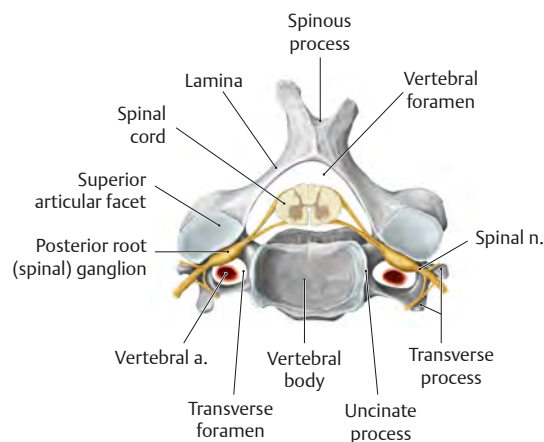
C Uncovertebral joints, split intervertebral disks, anterior view of coronal section.

**Clinical box 2.6****Proximity of the spinal nerve and vertebral artery to the uncinate process**

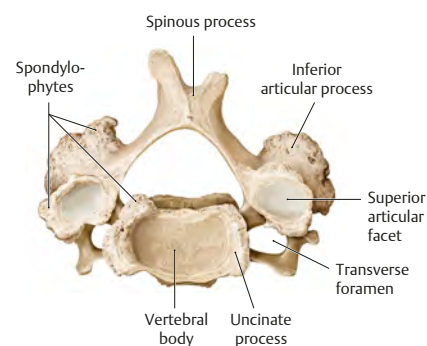
The spinal nerve and vertebral artery pass through the intervertebral and transverse foramina, respectively (**A** and **B**). Bony outgrowths (osteophytes) on the uncinate process (**C**) resulting from uncovertebral arthrosis (degeneration) may compress both the nerve and the artery and can lead to chronic pain in the cervical region.



A Cervical spine, anterior view.



B Fourth cervical vertebra, superior view.



C Advanced uncovertebral arthrosis of the fourth cervical vertebra, superior view.

Joints of the Vertebral Column: Craniovertebral Region

Back

Fig. 2.22 Craniovertebral joints

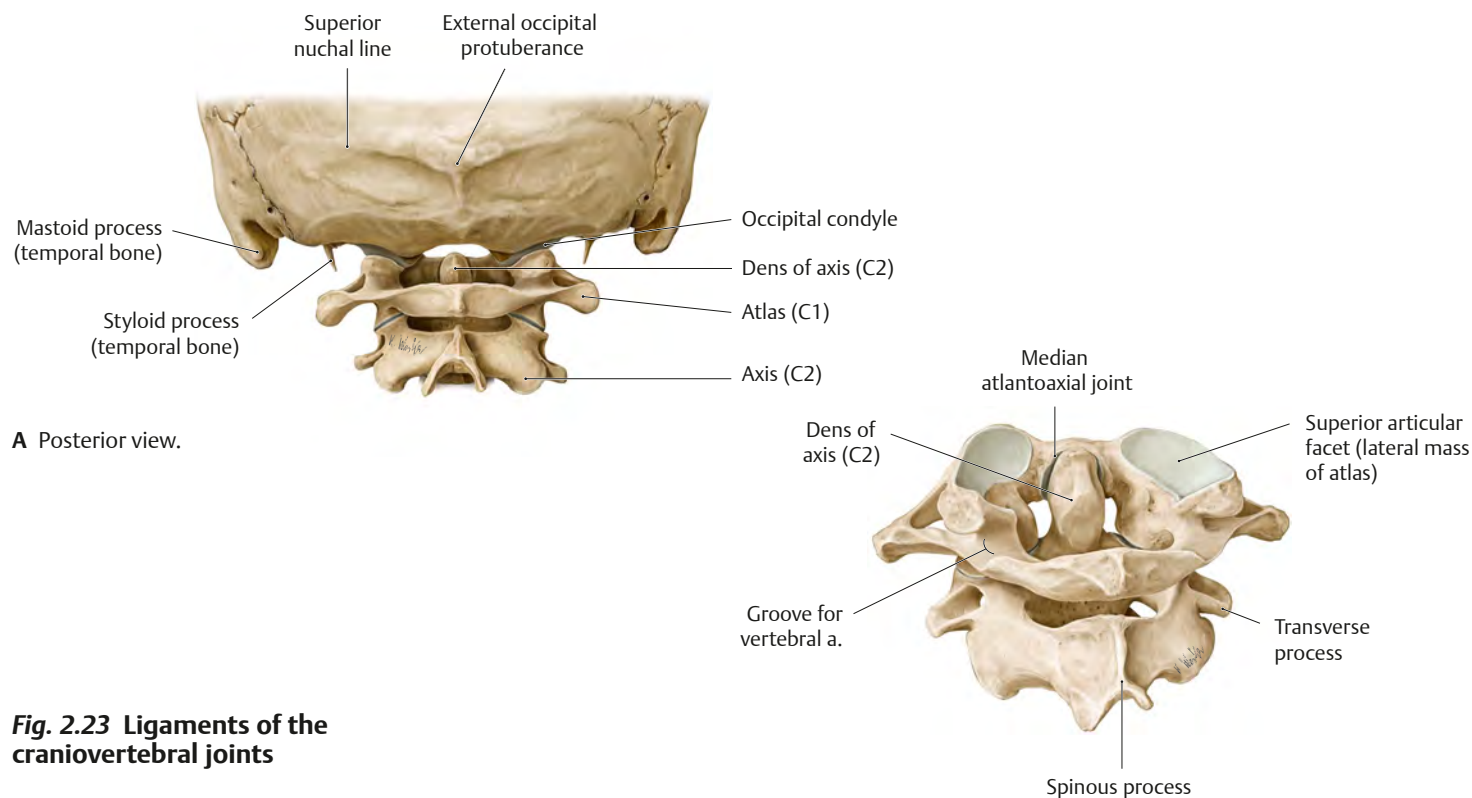
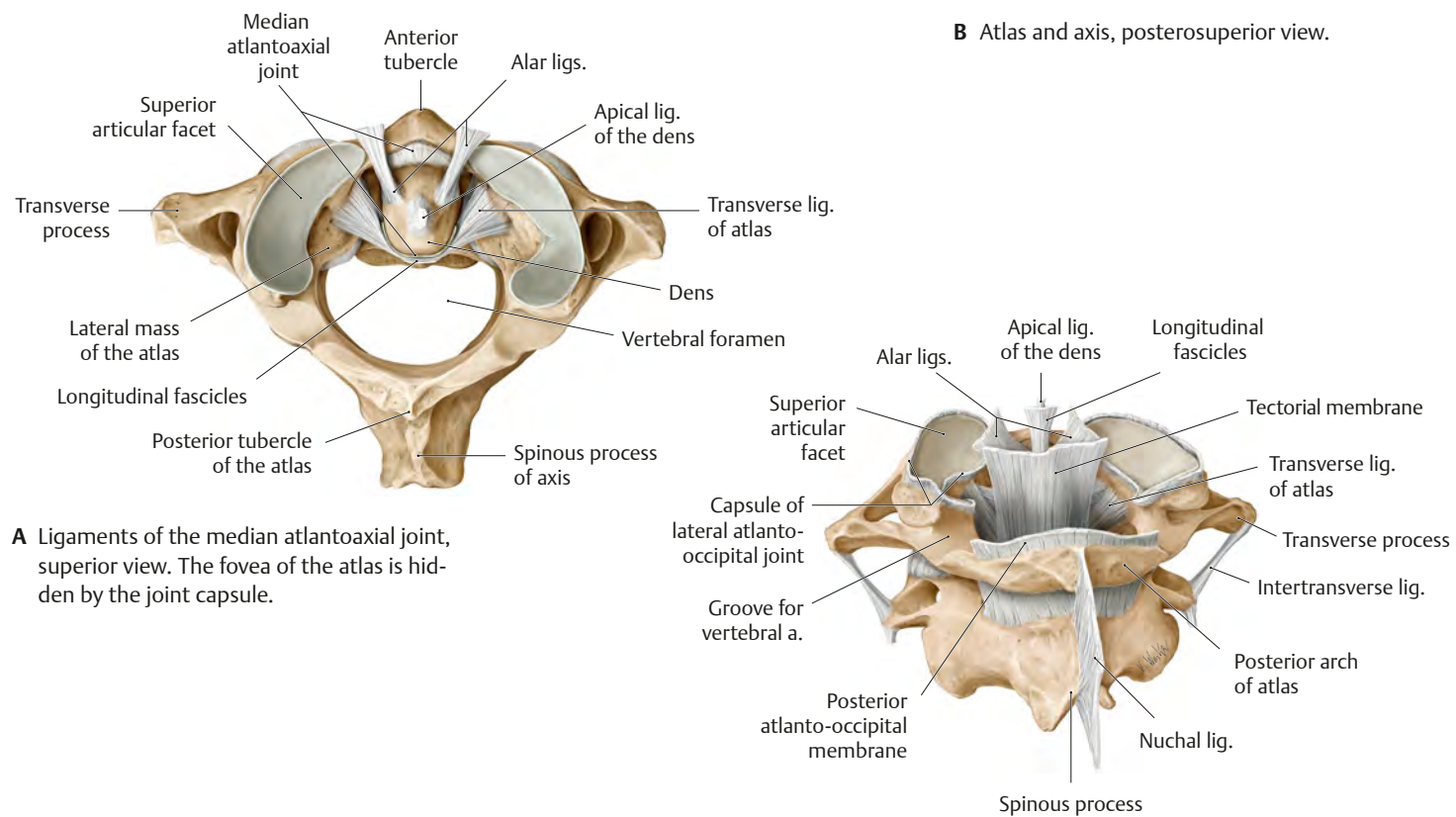


Fig. 2.23 Ligaments of the craniovertebral joints



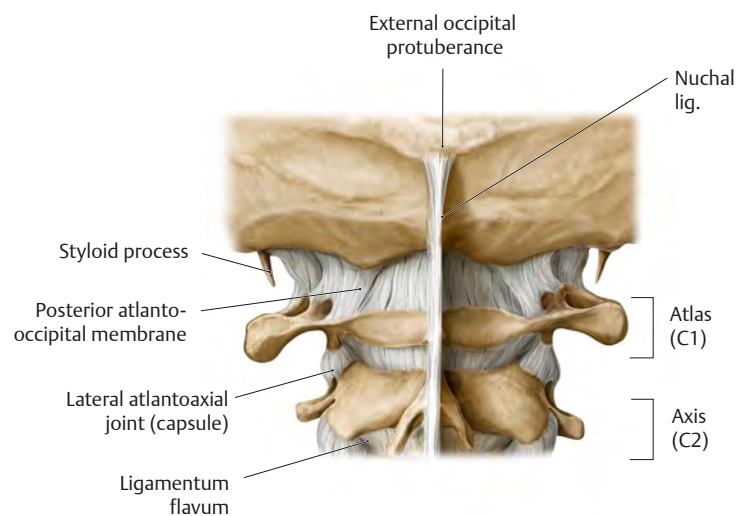
A Ligaments of the median atlantoaxial joint, superior view. The fovea of the atlas is hidden by the joint capsule.

B Ligaments of the craniovertebral joints, posterosuperior view. The dens of the axis is hidden by the tectorial membrane.

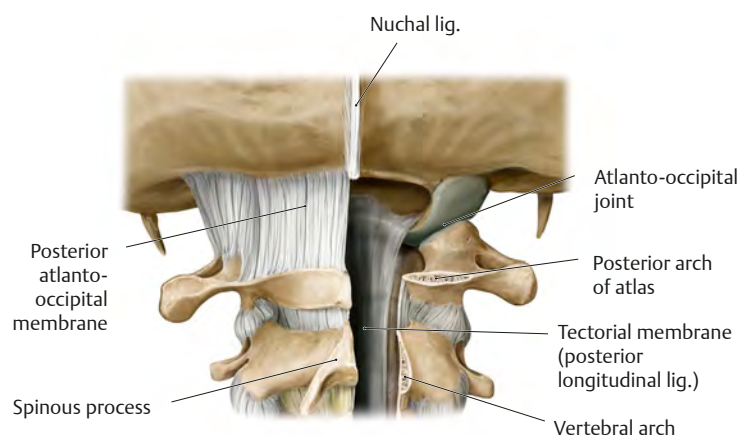
The atlanto-occipital joints are the two articulations between the convex occipital condyles of the occipital bone and the slightly concave superior articular facets of the atlas (C1). The atlantoaxial joints are

the two lateral and one medial articulations between the atlas (C1) and axis (C2).

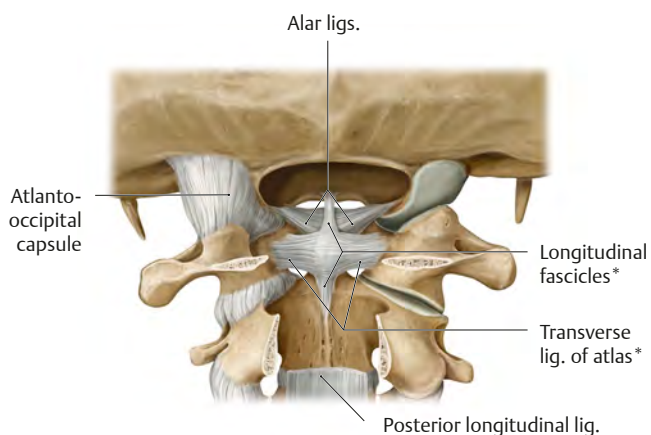
Fig. 2.24 Dissection of the craniovertebral joint ligaments



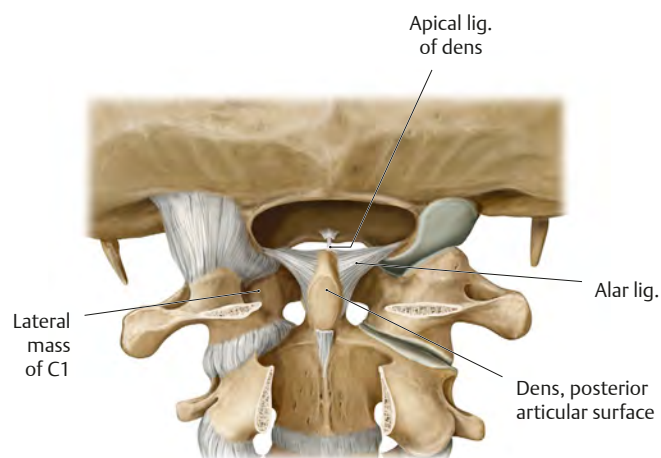
A Nuchal ligament and posterior atlanto-occipital membrane.



B Posterior longitudinal ligament. *Removed:* Spinal cord; vertebral canal windowed.



C Cruciform ligament of atlas (*). *Removed:* Tectorial membrane, posterior atlanto-occipital membrane, and vertebral arches.



D Alar and apical ligaments. *Removed:* Transverse ligament of atlas.

Vertebral Ligaments: Overview & Cervical Spine

The ligaments of the spinal column bind the vertebrae and enable the spine to withstand high mechanical loads and shearing stresses and

limit the range of motion. The ligaments are subdivided into vertebral body ligaments and vertebral arch ligaments.

Fig. 2.25 Vertebral ligaments
Viewed obliquely from the left posterior view.

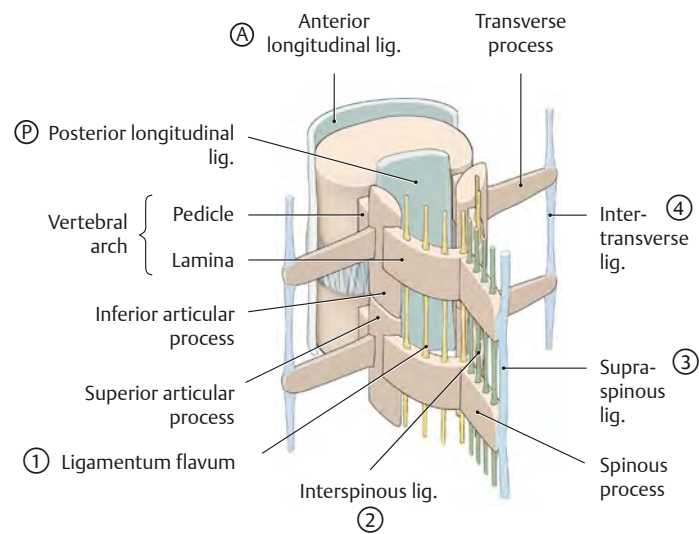


Table 2.3 Vertebral ligaments		
Ligament		Location
Vertebral body ligaments		
(A)	Anterior longitudinal lig.	Along anterior surface of vertebral body
(P)	Posterior longitudinal lig.	Along posterior surface of vertebral body
Vertebral arch ligaments		
(1)	Ligamentum flavum	Between laminae
(2)	Interspinous lig.	Between spinous process
(3)	Supraspinous lig.	Along posterior ridge of spinous processes
(4)	Intertransverse lig.	Between transverse processes
Nuchal lig.*		Between external occipital protuberance and spinous process of C7
*Corresponds to a supraspinous ligament that is broadened superiorly.		

Fig. 2.26 Anterior longitudinal ligament
Anterior view with base of skull removed.

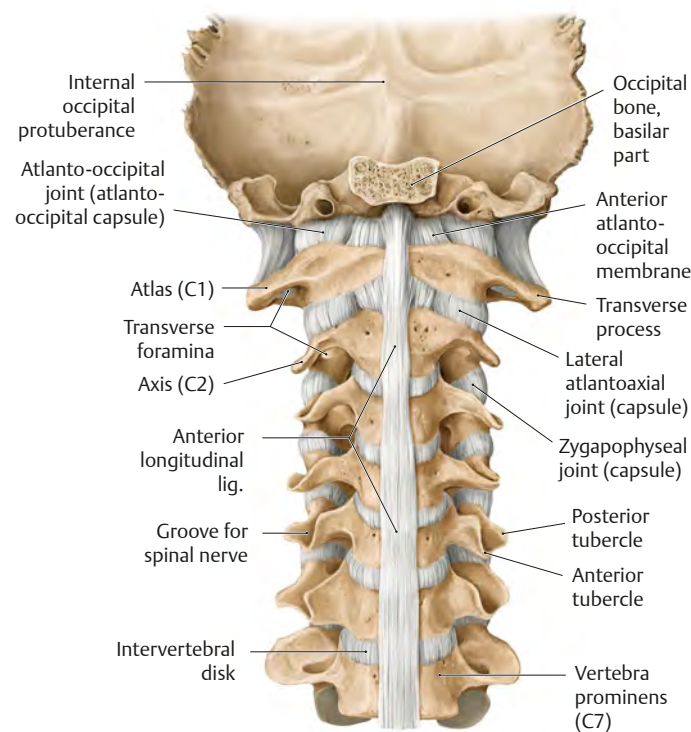


Fig. 2.27 Posterior longitudinal ligament
Posterior view with vertebral canal opened via laminectomy and spinal cord removed. The tectorial membrane is a broadened expansion of the posterior longitudinal ligament.

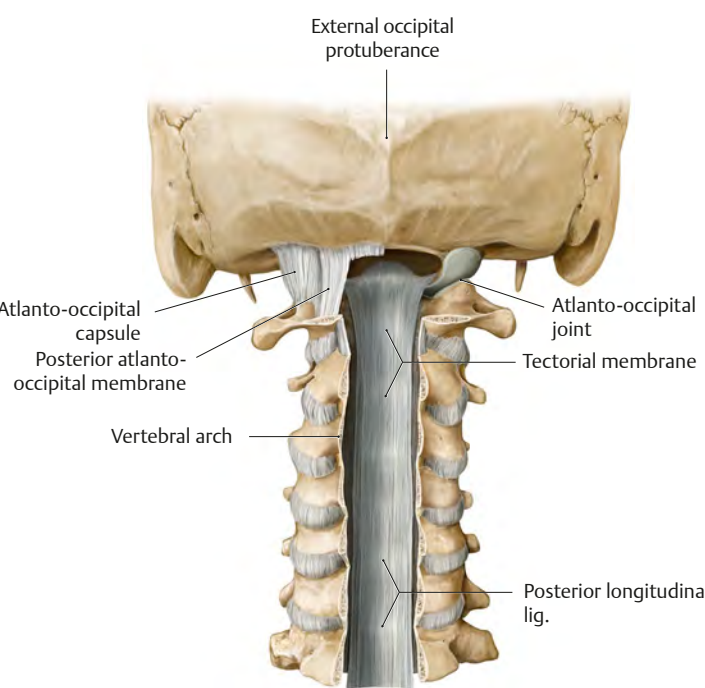
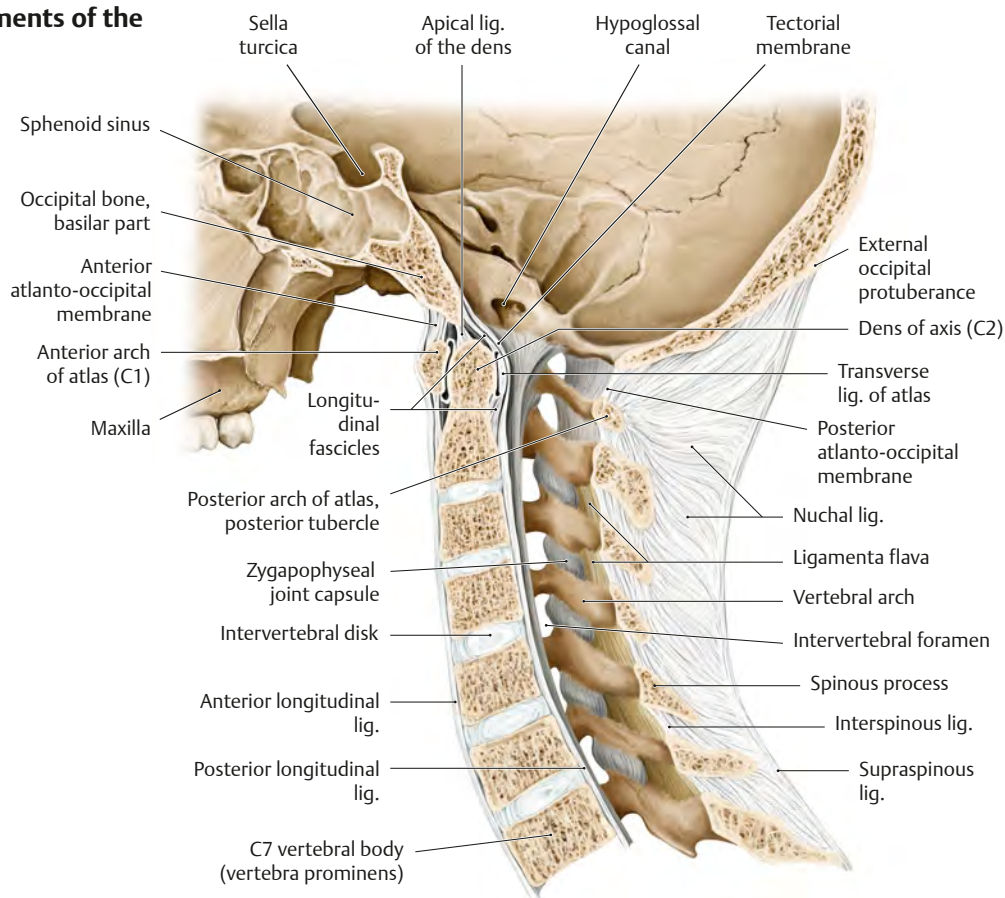
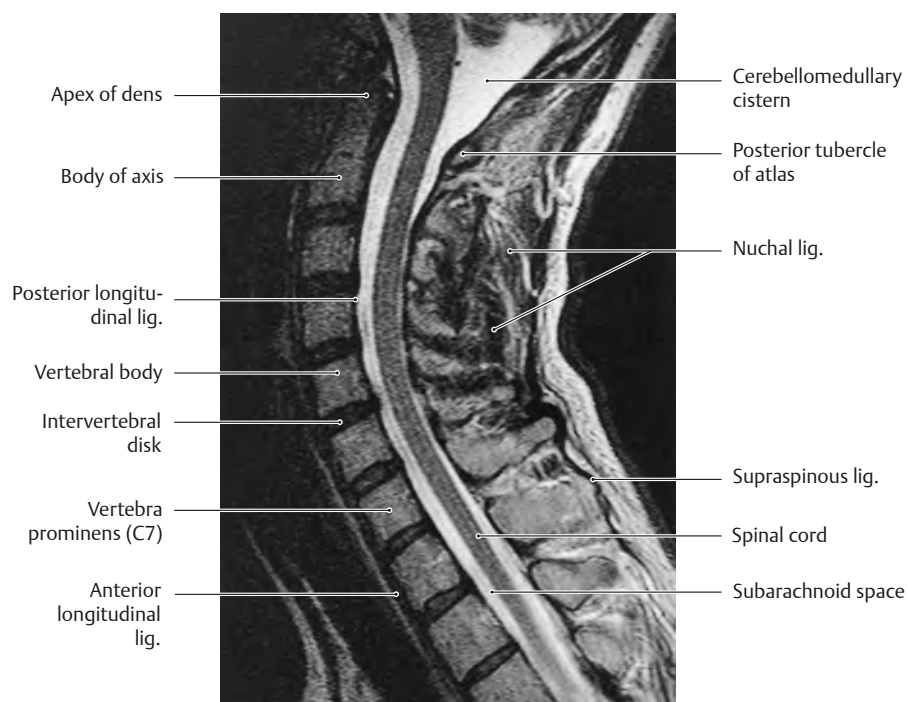


Fig. 2.28 Ligaments of the cervical spine
Mid-sagittal view.



A Midsagittal section, left lateral view. The nuchal ligament is the broadened, sagittally oriented part of the supraspinous ligament that extends from the vertebra prominens (C7) to the external occipital protuberance.



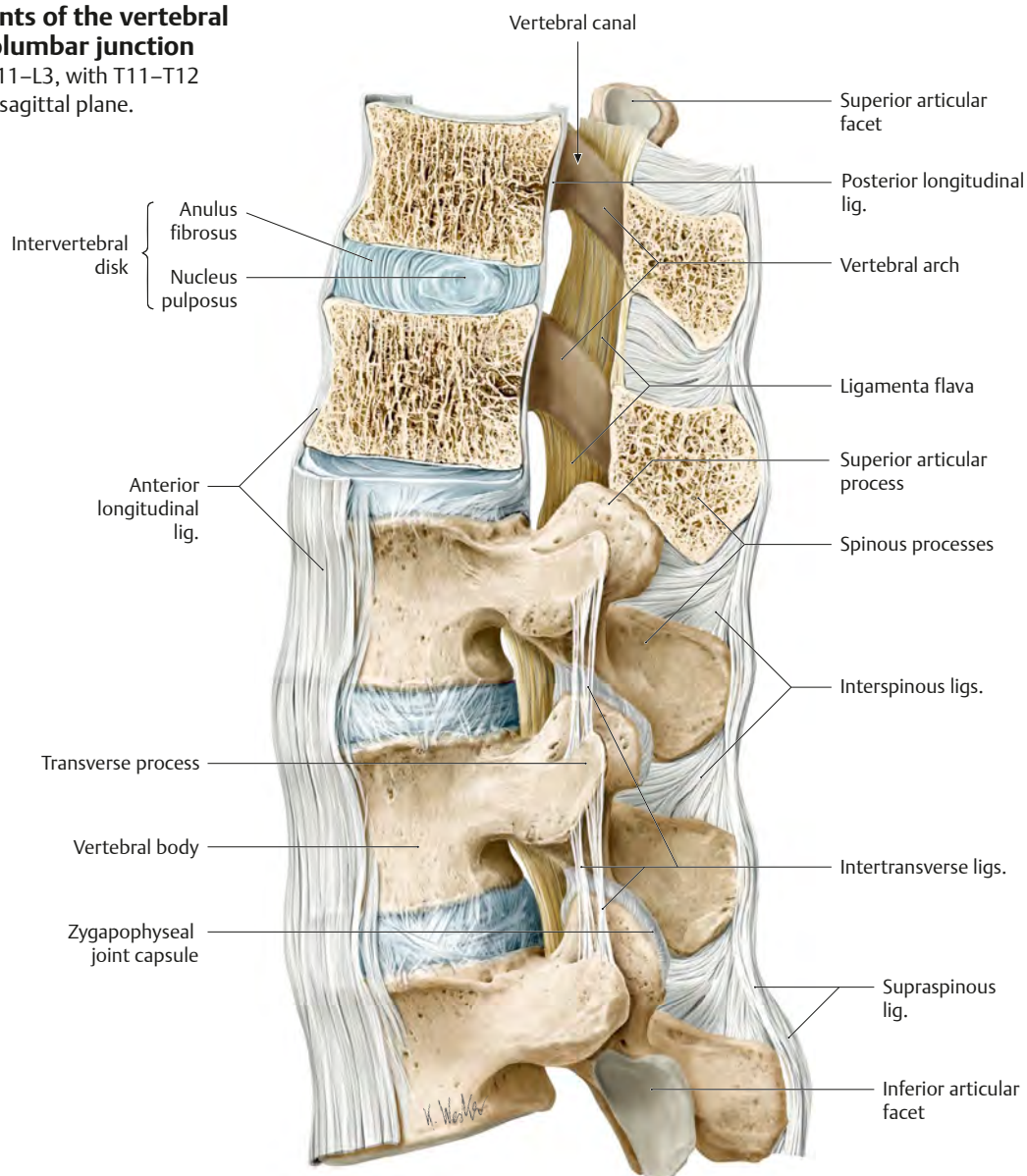
B Midsagittal T2-weighted MRI, left lateral view.

Vertebral Ligaments: Thoracolumbar Spine

Back

Fig. 2.29 Ligaments of the vertebral column: Thoracolumbar junction

Left lateral view of T11–L3, with T11–T12 sectioned in the midsagittal plane.



Clinical box 2.7

Spinal fusion procedure

Spinal fusion is a surgical procedure used to restore stability to the vertebral column or to eliminate painful motion. The basic idea involves fusing two or more vertebrae so they will heal into a single, solid bone. Fusions can take place at any part of the vertebral column.



A Midline cutaway



B Posterior view

Fig. 2.30 Anterior longitudinal ligament

Anterior view of L3–L5.

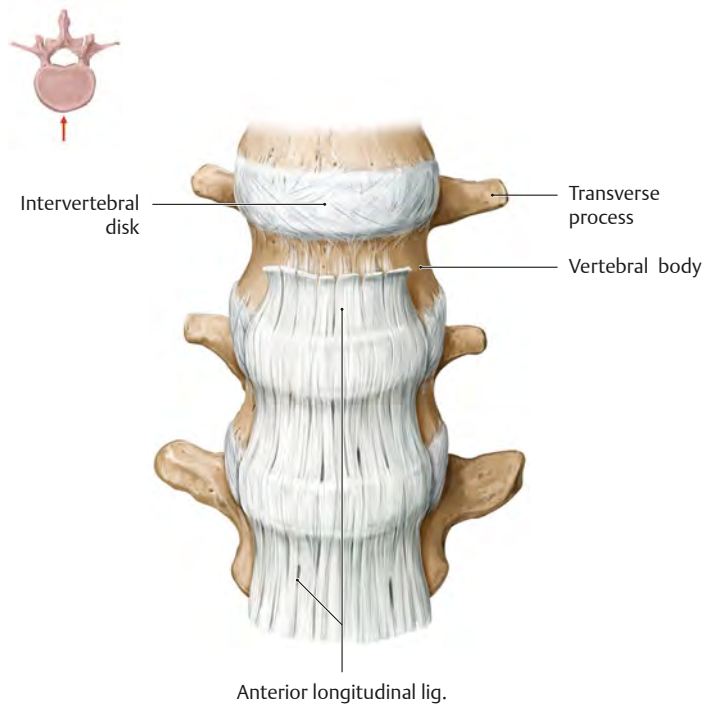


Fig. 2.32 Posterior longitudinal ligament

Posterior view of opened vertebral canal at level of L2–L5.

Removed: L2–L4 vertebral arches at pedicular level.

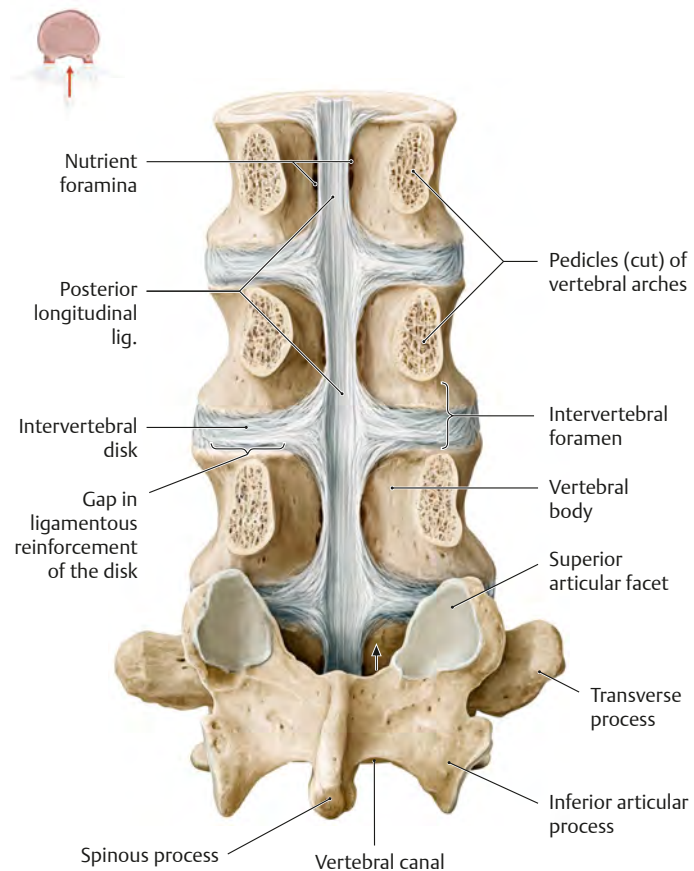
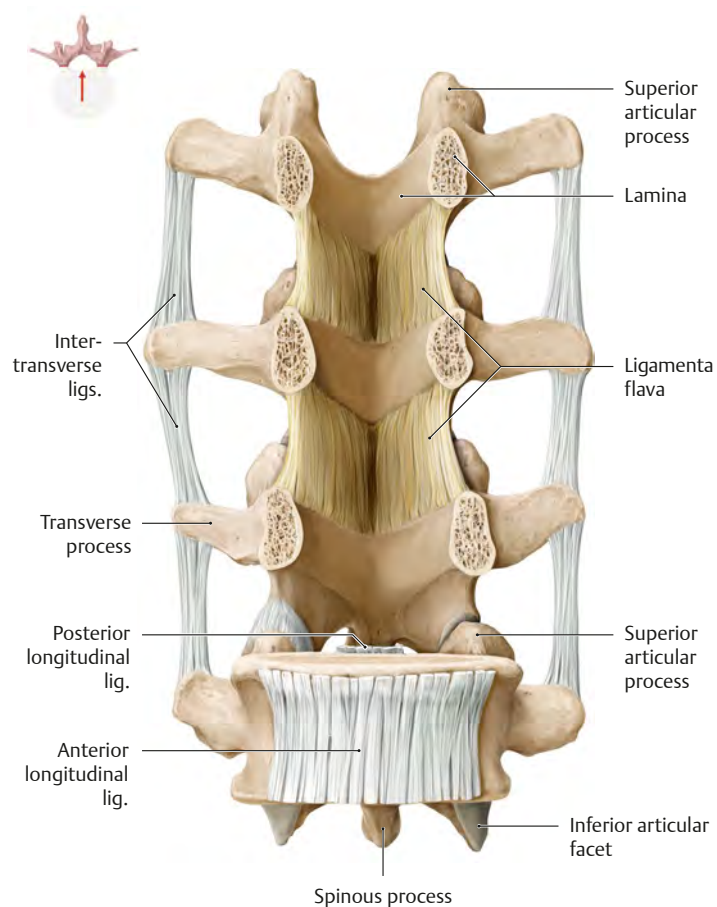


Fig. 2.31 Ligamenta flava and intertransverse ligaments

Anterior view of opened vertebral canal at level of L2–L5.

Removed: L2–L4 vertebral bodies.



3 Muscles

Muscles of the Back: Overview

The muscles of the back are divided into two groups, the extrinsic and the intrinsic muscles, which are separated by the posterior layer of the thoracolumbar fascia. The superficial extrinsic muscles are

considered muscles of the upper limb that have migrated to the back; these muscles are discussed in the Upper Limb, pp. 312–317.

Fig. 3.1 Superficial extrinsic muscles of the back
 Posterior view. *Removed:* Trapezius and latissimus dorsi (right). *Revealed:* Thoracolumbar fascia. *Note:* The posterior layer of the thoracolumbar fascia is reinforced by the aponeurotic origin of the latissimus dorsi.

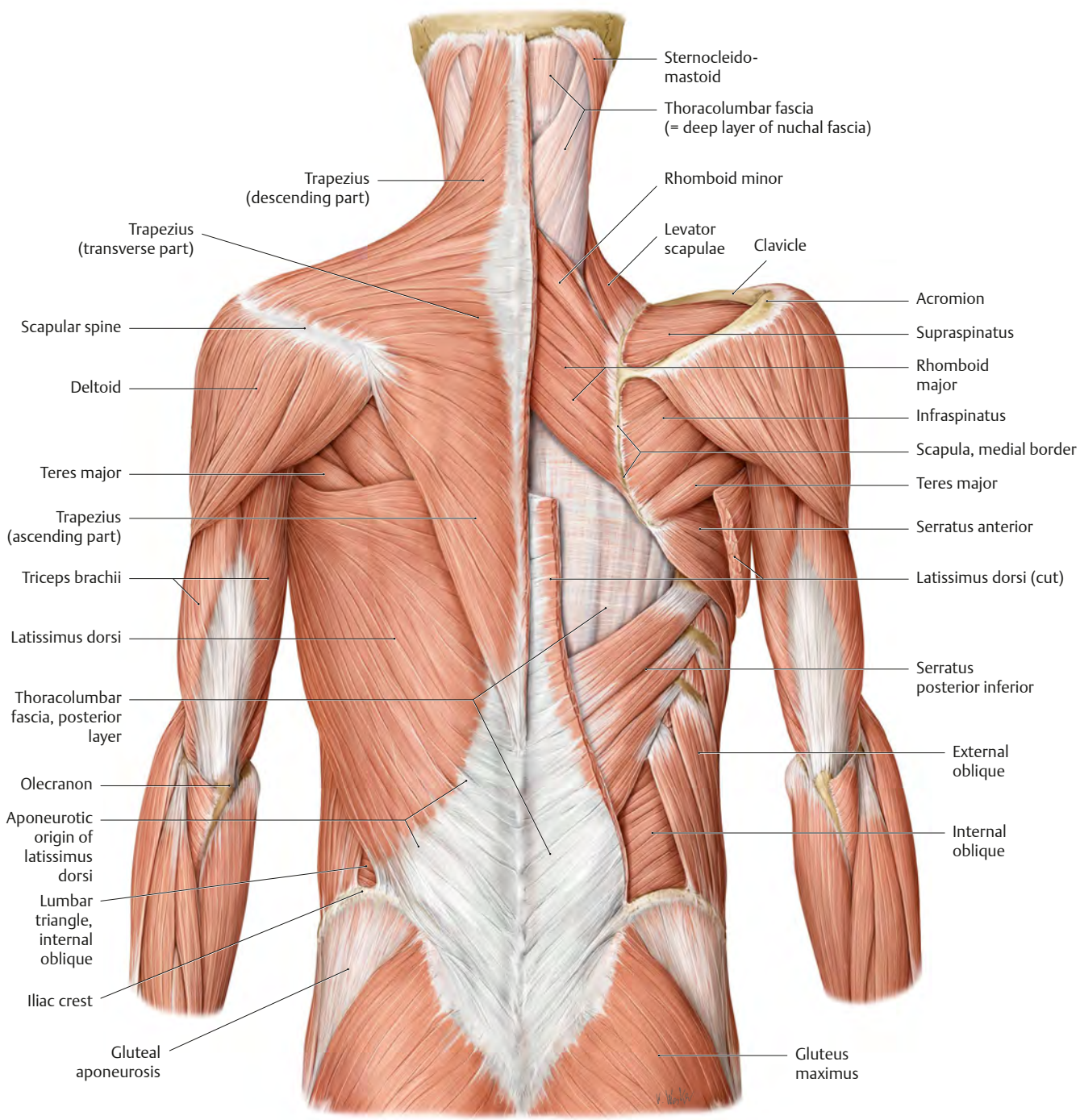
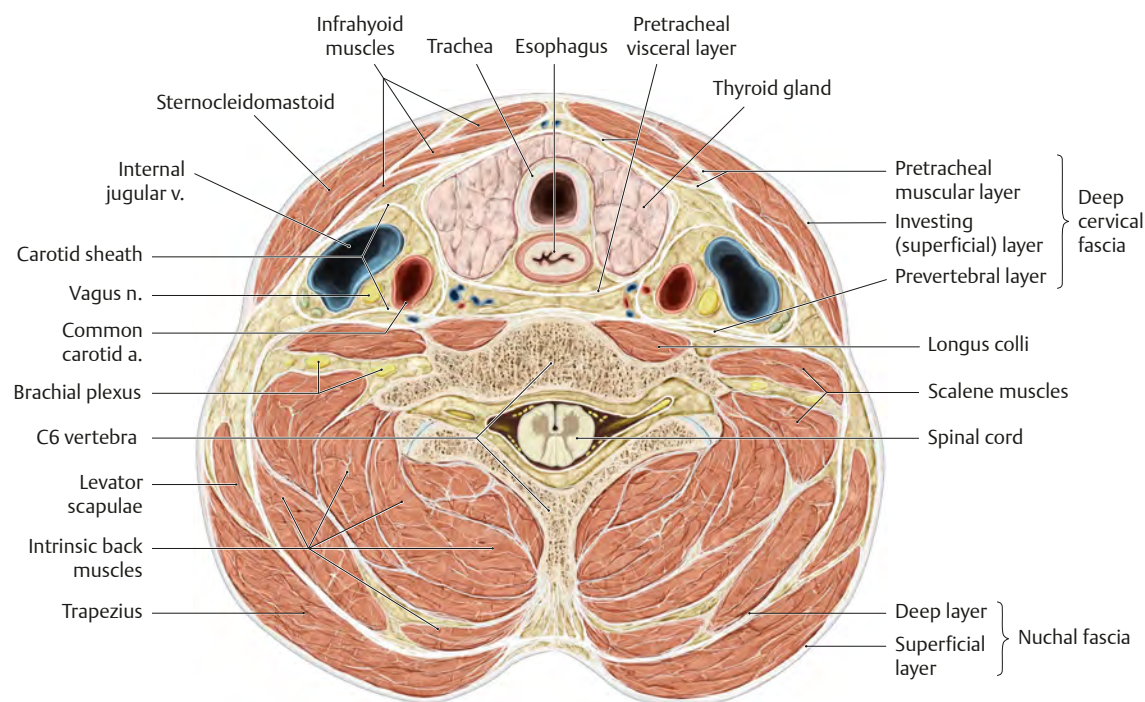


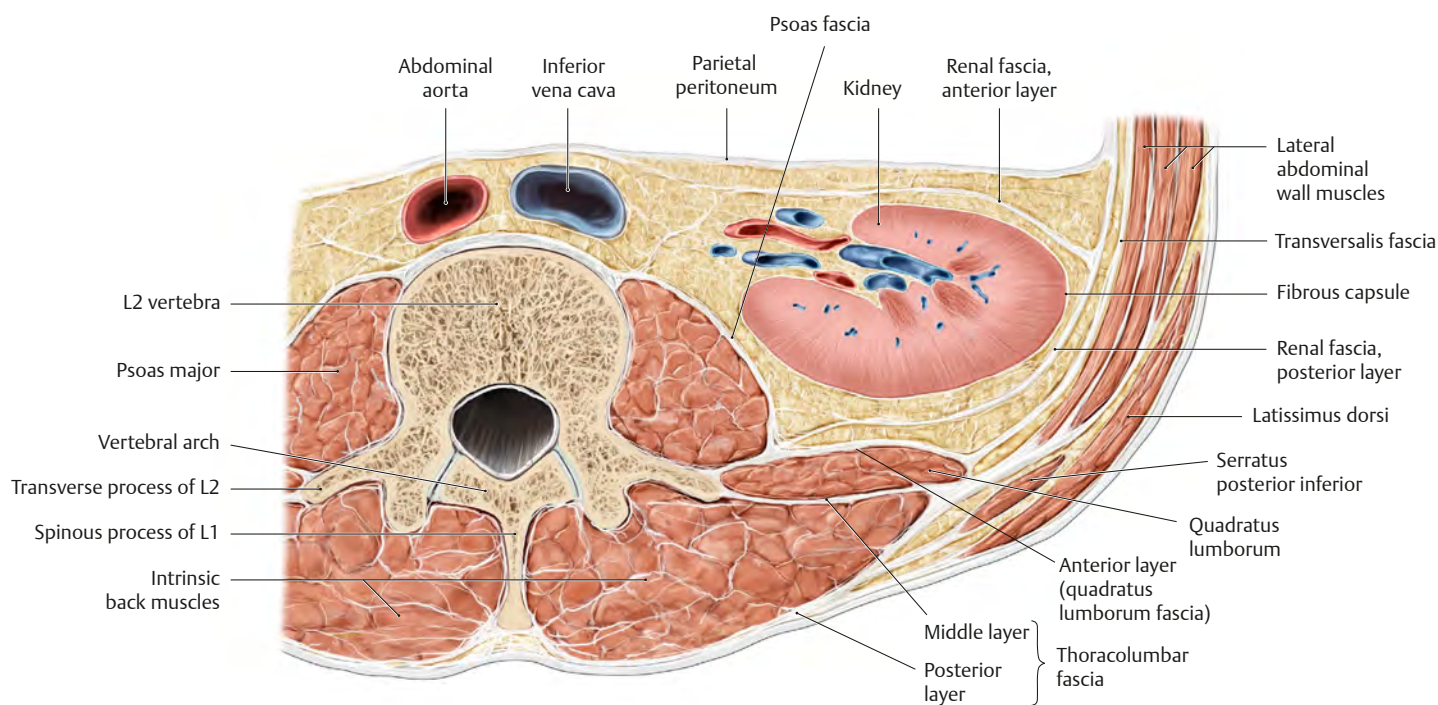
Fig. 3.2 Thoracolumbar fascia

Transverse section, superior view. The intrinsic back muscles are sequestered in an osseofibrous canal, formed by the thoracolumbar fascia, the vertebral arches, and the spinous and transverse processes of associated vertebrae. The thoracolumbar fascia consists of a posterior

and middle layer that unite at the lateral margin of the intrinsic back muscles. In the neck, the posterior layer blends with the nuchal fascia (deep layer), becoming continuous with the deep cervical fascia (pre-vertebral layer).



A Transverse section at level of C6 vertebra, superior view.



B Transverse section at level of L2, superior view.
Removed: Cauda equina and anterior trunk wall.

Intrinsic Muscles of the Cervical Spine

Back

Fig. 3.3 Muscles in the nuchal region

Posterior view. *Removed:* Trapezius, sternocleidomastoid, splenius, and semispinalis muscles (right). *Revealed:* Nuchal muscles (right).

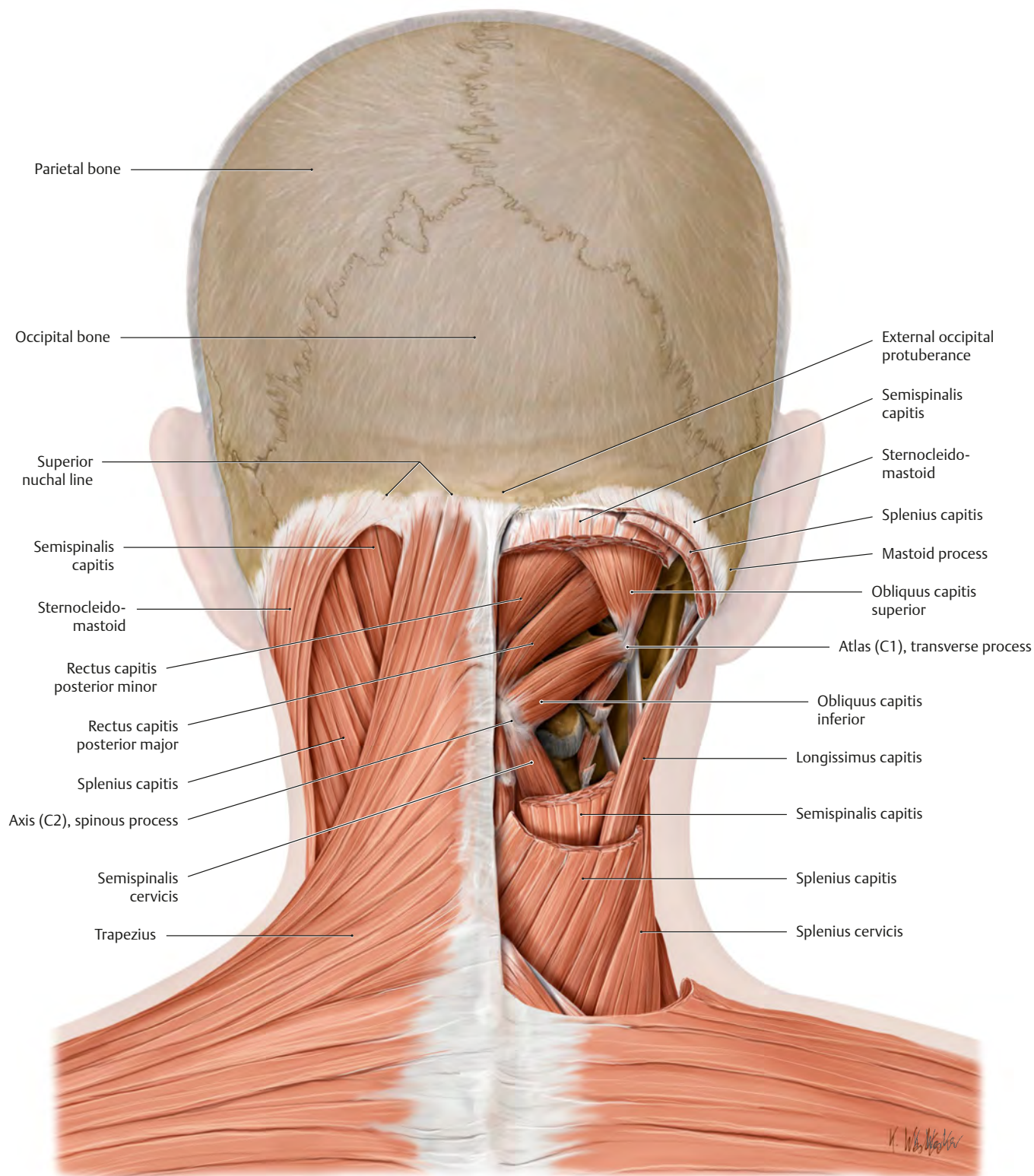
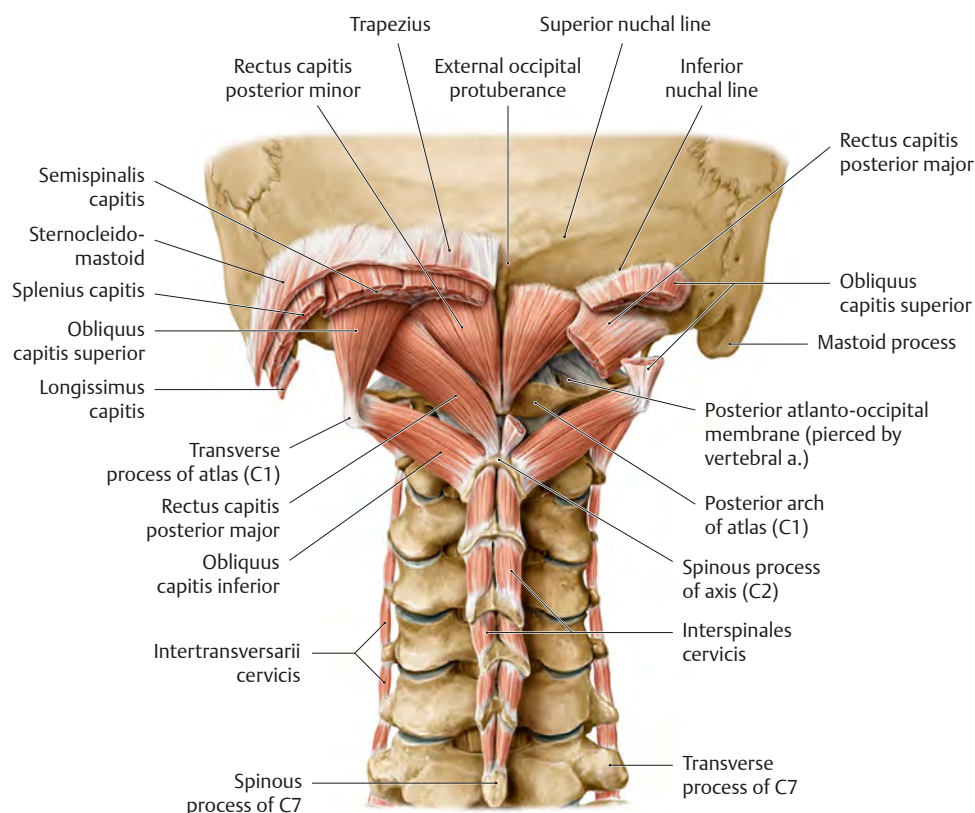


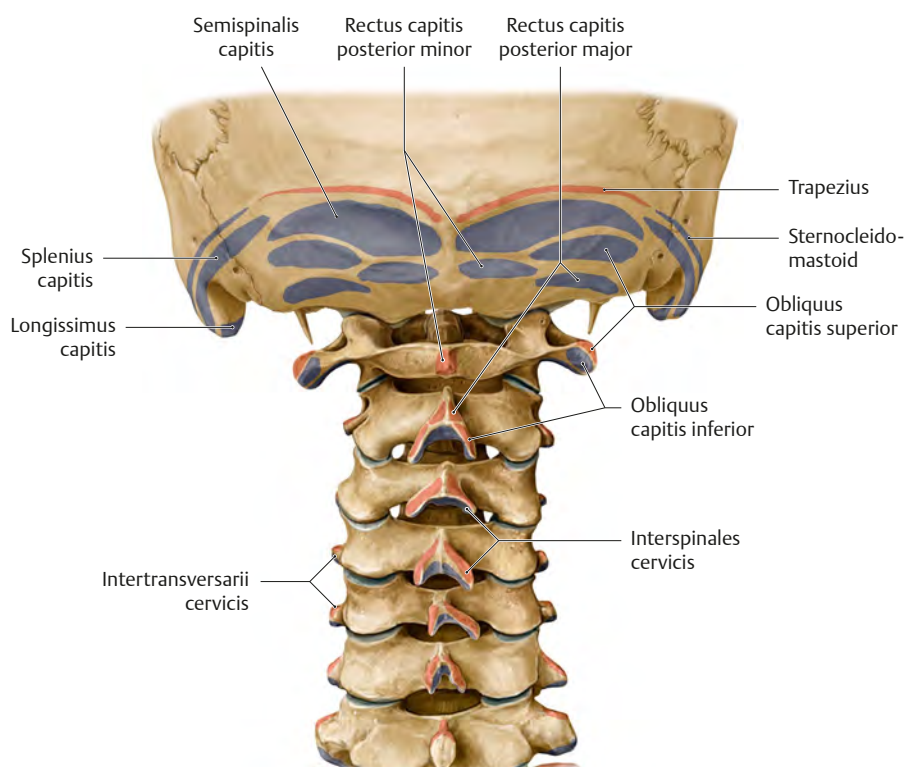
Fig. 3.4 Short nuchal muscles

Posterior view. See **Fig. 3.6**. Three of the short nuchal muscles (obliquus capitis inferior, obliquus capitis superior and the rectus

capitis posterior major) form the boundaries of the suboccipital triangle (region).



A Course of the short nuchal muscles.



B Suboccipital region. Muscle origins are shown in red, insertions in blue.

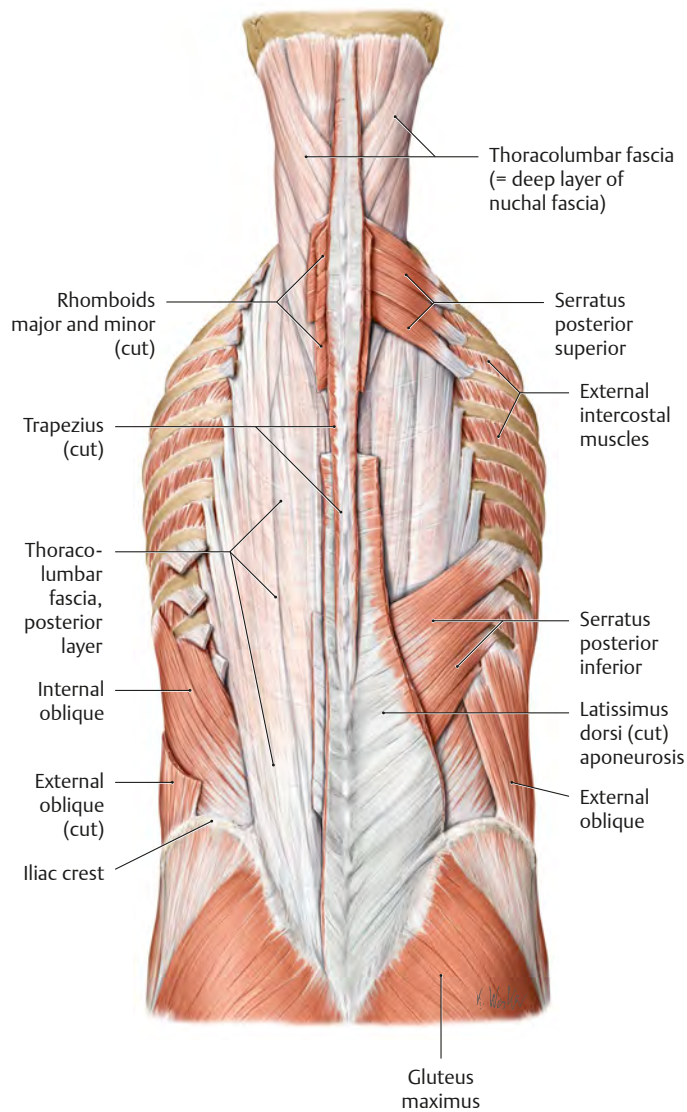
Intrinsic Muscles of the Back

The extrinsic muscles of the back (trapezius, latissimus dorsi, levator scapulae, and rhomboids) are discussed in the Upper Limb, pp. 312–313. The serratus posterior, considered an intermediate

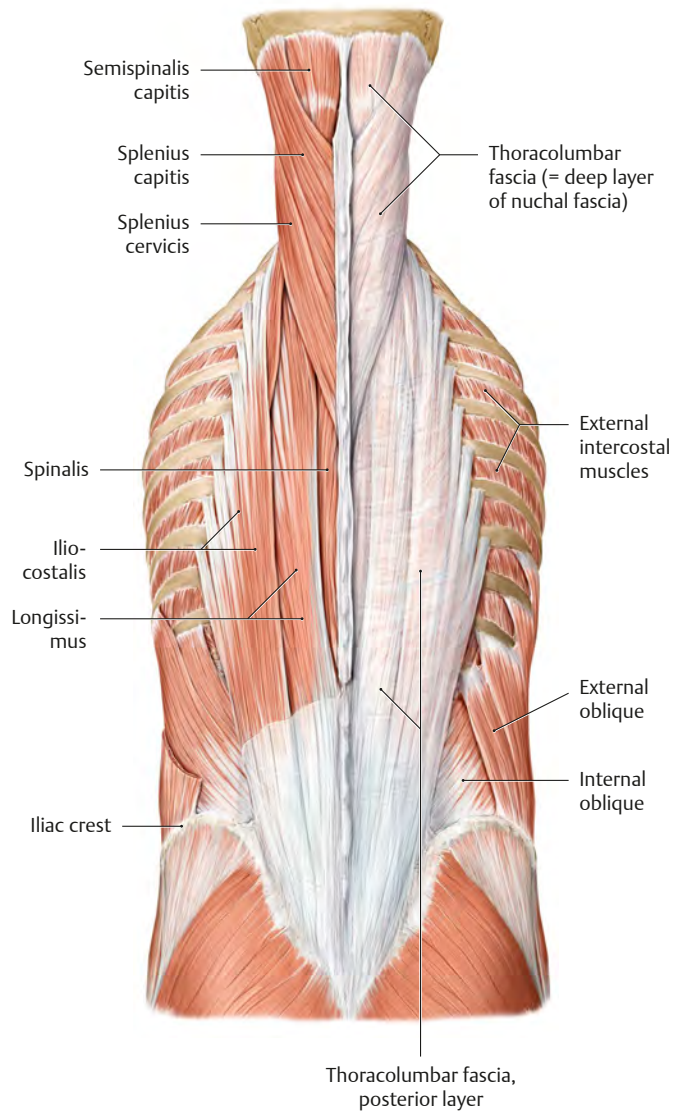
extrinsic back muscle, has been included with the superficial intrinsic muscles in this unit.

Fig. 3.5 Intrinsic muscles of the back

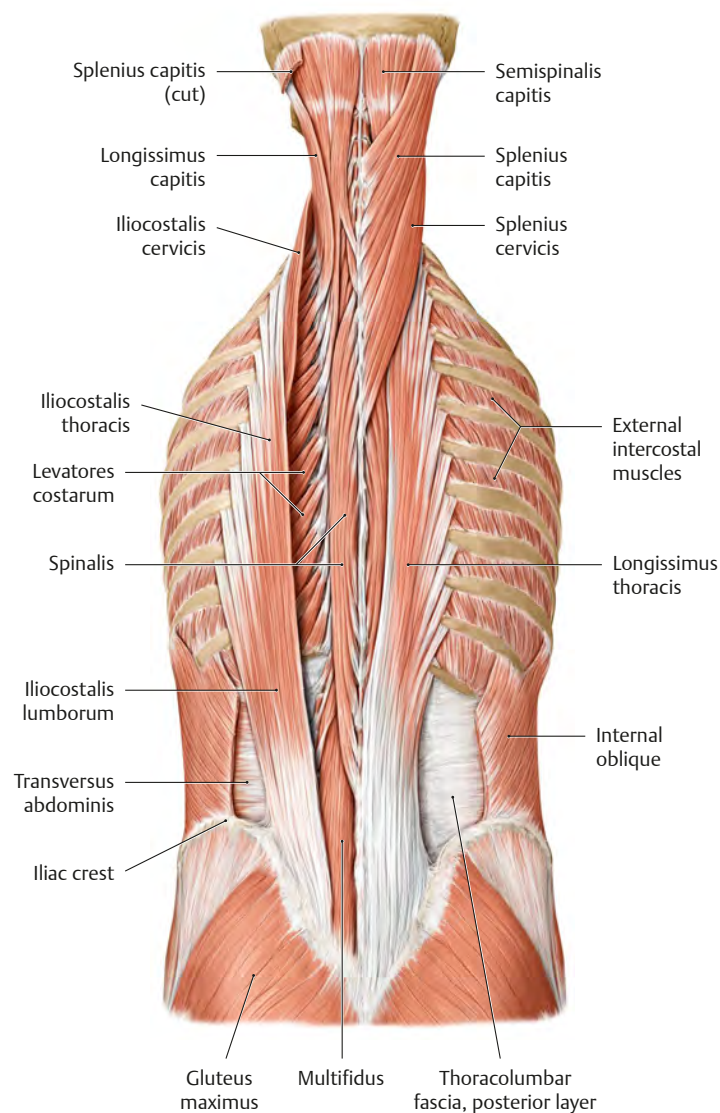
Posterior view. Sequential dissection of the thoracolumbar fascia, superficial intrinsic muscles, intermediate intrinsic muscles, and deep intrinsic muscles of the back.



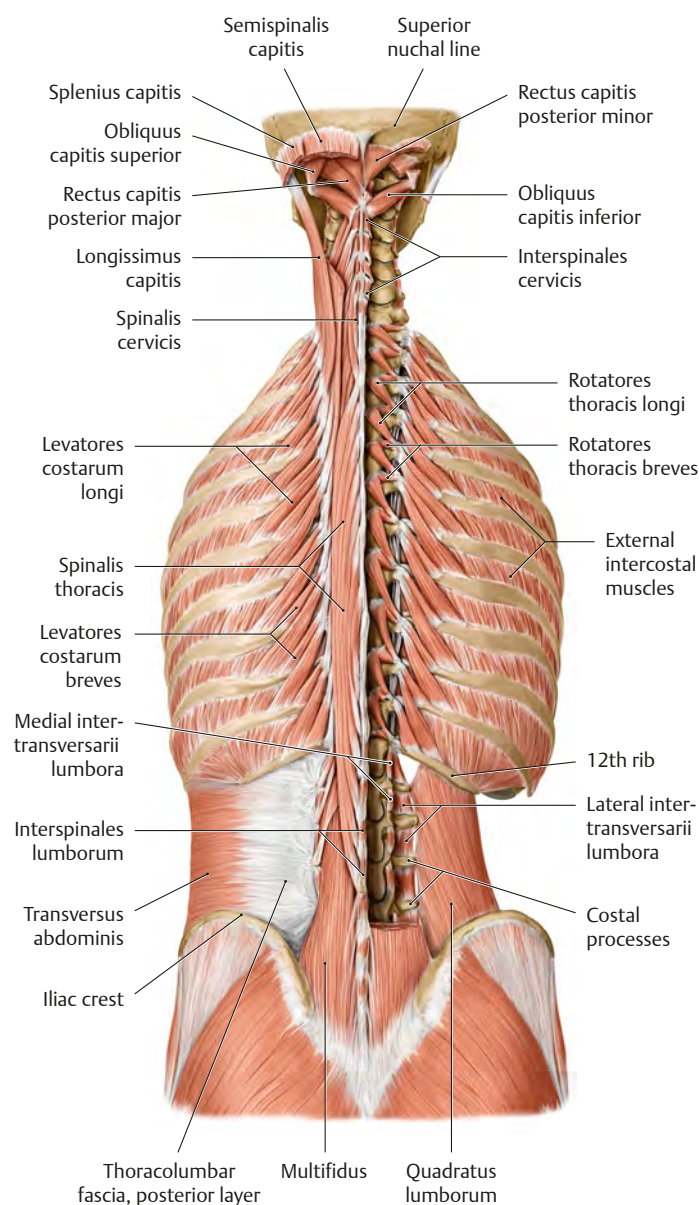
A Thoracolumbar fascia. *Removed:* Shoulder girdles and extrinsic back muscles (except serratus posterior and aponeurotic origin of latissimus dorsi). *Revealed:* Posterior layer of thoracolumbar fascia.



B Superficial and intermediate intrinsic back muscles. *Removed:* Thoracolumbar fascia, posterior layer (left). *Revealed:* Erector spinae and splenius muscles.



C Intermediate and deep intrinsic back muscles. *Removed:* Longissimus thoracis and cervicis, splenius muscles (left); iliocostalis (right). *Note:* The posterior layer of the thoracolumbar fascia gives origin to the internal oblique and transversus abdominis. *Revealed:* Deep muscles of the back.



D Deep intrinsic back muscles. *Removed:* Superficial and intermediate intrinsic back muscles (all); deep fascial layer and multifidus (right). *Revealed:* Intertransversarii and quadratus lumborum (right).

Muscle Facts (I)

Fig. 3.6 Short nuchal and craniovertebral joint muscles

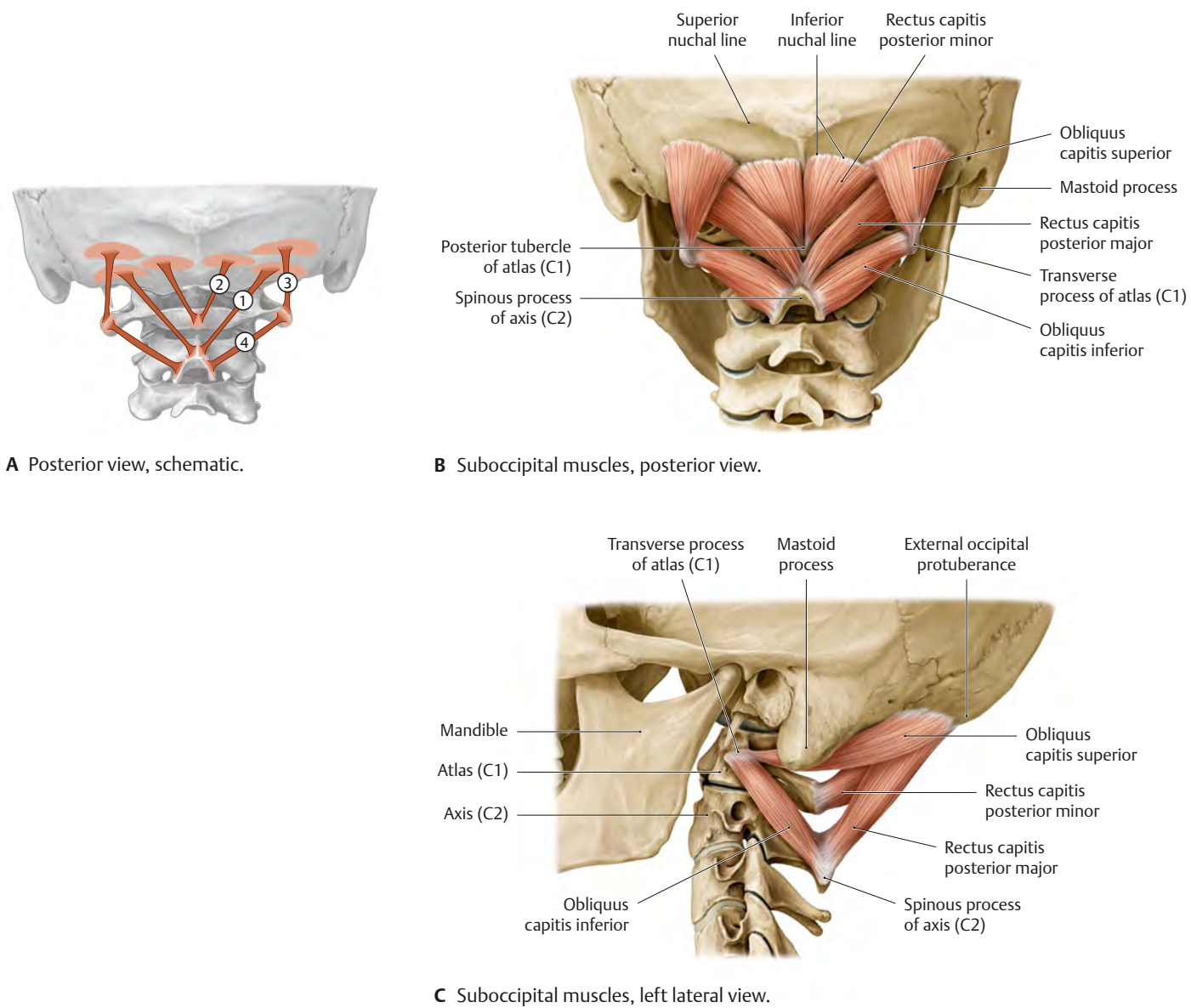
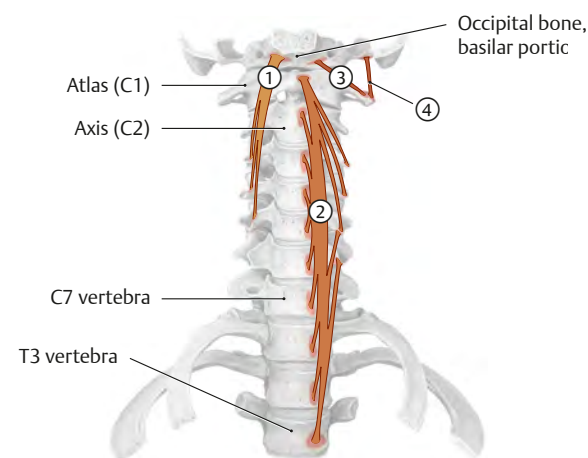
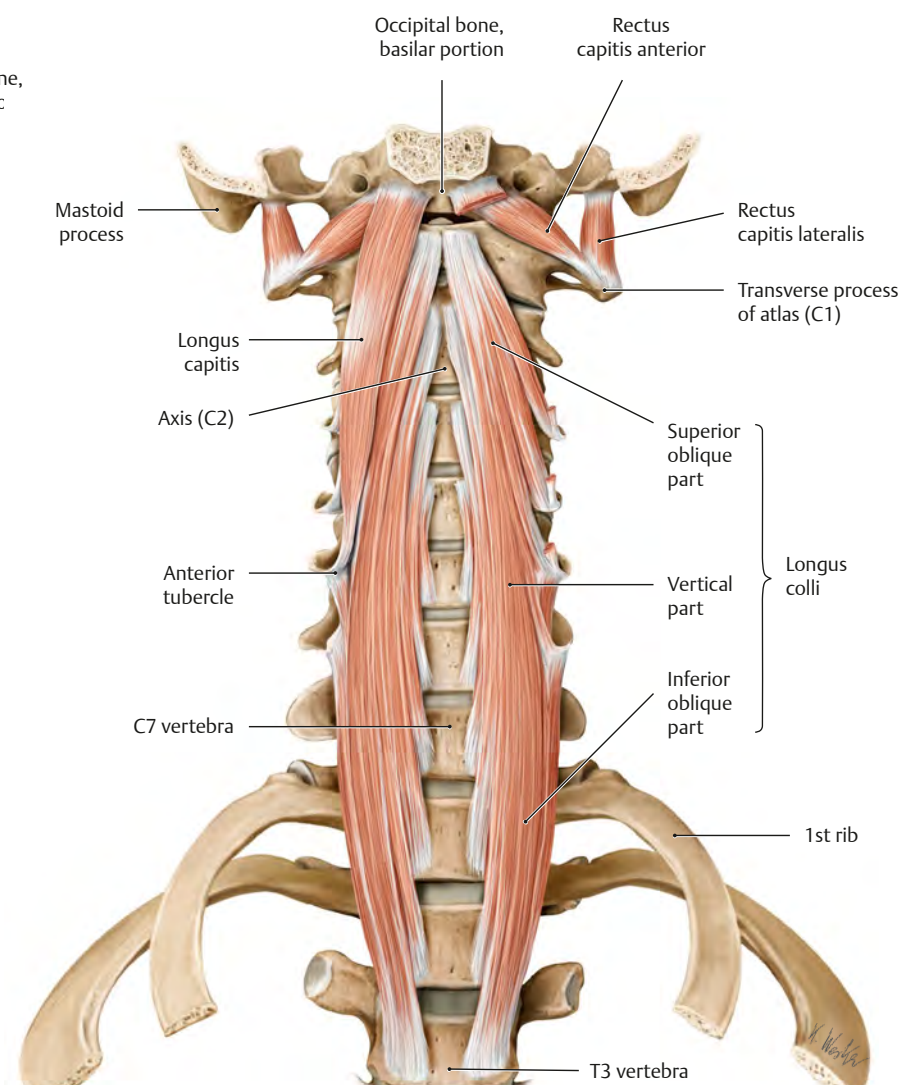


Table 3.1 Short nuchal and craniovertebral joint muscles					
Muscle		Origin	Insertion	Innervation	Action
Rectus capitis posterior	① Rectus capitis posterior major	C2 (spinous process)	Occipital bone (inferior nuchal line, middle third)	C1 (posterior ramus = suboccipital n.)	<i>Bilateral:</i> Extends head <i>Unilateral:</i> Rotates head to same side
	② Rectus capitis posterior minor	C1 (posterior tubercle)	Occipital bone (inferior nuchal line, inner third)		
Obliquus capitis	③ Obliquus capitis superior	C1 (transverse process)	Occipital bone (inferior nuchal line, middle third; above rectus capitis posterior major)		<i>Bilateral:</i> Extends head <i>Unilateral:</i> Flexes head to same side; rotates to opposite side
	④ Obliquus capitis inferior	C2 (spinous process)	C1 (transverse process)		<i>Bilateral:</i> Extends head <i>Unilateral:</i> Rotates head to same side

Fig. 3.7 Prevertebral muscles



A Anterior view, schematic.



B Prevertebral muscles, anterior view.
 Removed: Longus capitis (left); cervical viscera.

Table 3.2

Prevertebral muscles

Muscle	Origin	Insertion	Innervation	Action
① Longus capitis	C3–C6 (transverse processes, anterior tubercles)	Occipital bone (basilar part)	Direct branches from cervical plexus (C1–C3)	<i>Bilateral:</i> Flexes head <i>Unilateral:</i> Flexes and slightly rotates head to same side
② Longus colli (cervicis)	Vertical (medial) part	C5–T3 (anterior sides of vertebral bodies)	Direct branches from cervical plexus (C2–C6)	<i>Bilateral:</i> Flexes cervical spine <i>Unilateral:</i> Flexes and rotates cervical spine to same side
	Superior oblique part	C3–C5 (transverse processes, anterior tubercles)		
	Inferior oblique part	T1–T3 (anterior sides of vertebral bodies)		
③ Rectus capitis anterior	C1 (lateral mass)	Occipital bone (basilar part)	C1 (anterior ramus)	<i>Bilateral:</i> Flexion at atlanto-occipital joint <i>Unilateral:</i> Lateral flexion at atlanto-occipital joint
④ Rectus capitis lateralis	C1 (transverse process)	Occipital bone (basilar part, lateral to occipital condyles)		

Muscle Facts (II)

The intrinsic back muscles are divided into superficial, intermediate, and deep layers. The serratus posterior muscles are extrinsic back muscles, innervated by the anterior rami of intercostal nerves, not

the posterior rami, which innervate the intrinsic back muscles. They are included here as they are encountered in dissection of the back musculature.

Table 3.3 Superficial intrinsic back muscles					
Muscle		Origin	Insertion	Innervation	Action
Serratus posterior	① Serratus posterior superior	Nuchal lig.; C7–T3 (spinous processes)	2nd–4th ribs (superior borders)	Spinal nn. T2–T5 (anterior rami)	Elevates ribs
	② Serratus posterior inferior	T11–L2 (spinous processes)	8th–12th ribs (inferior borders, near angles)	Spinal nn. T9–T12 (anterior rami)	Depresses ribs
Splenius	③ Splenius capitis	Nuchal lig.; C7–T3 or T4 (spinous processes)	Lateral 1/3 nuchal line (occipital bone); mastoid process (temporal bone)	Spinal nn. C1–C6 (posterior rami, lateral branches)	<i>Bilateral:</i> Extends cervical spine and head <i>Unilateral:</i> Laterally flexes and rotates head to the same side
	④ Splenius cervicis	T3–T6 or T7 (spinous processes)	C1–C3/4 (transverse processes)		

Fig. 3.8 Superficial intrinsic back muscles, schematic
Right side, posterior view.

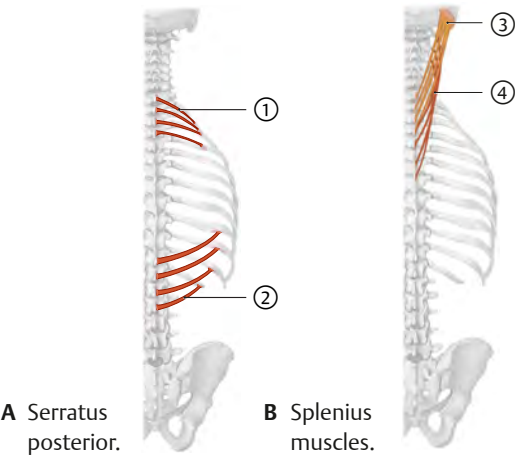


Fig. 3.9 Intermediate intrinsic back muscles, schematic
Right side, posterior view. These muscles are collectively known as the erector spinae.

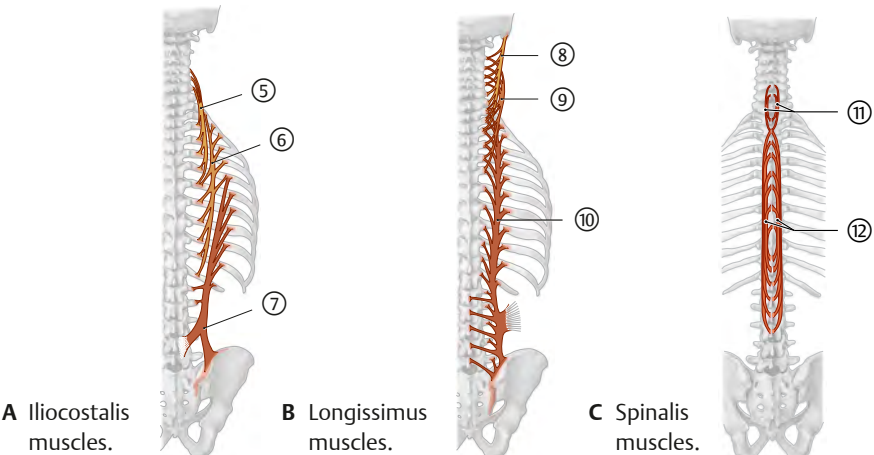
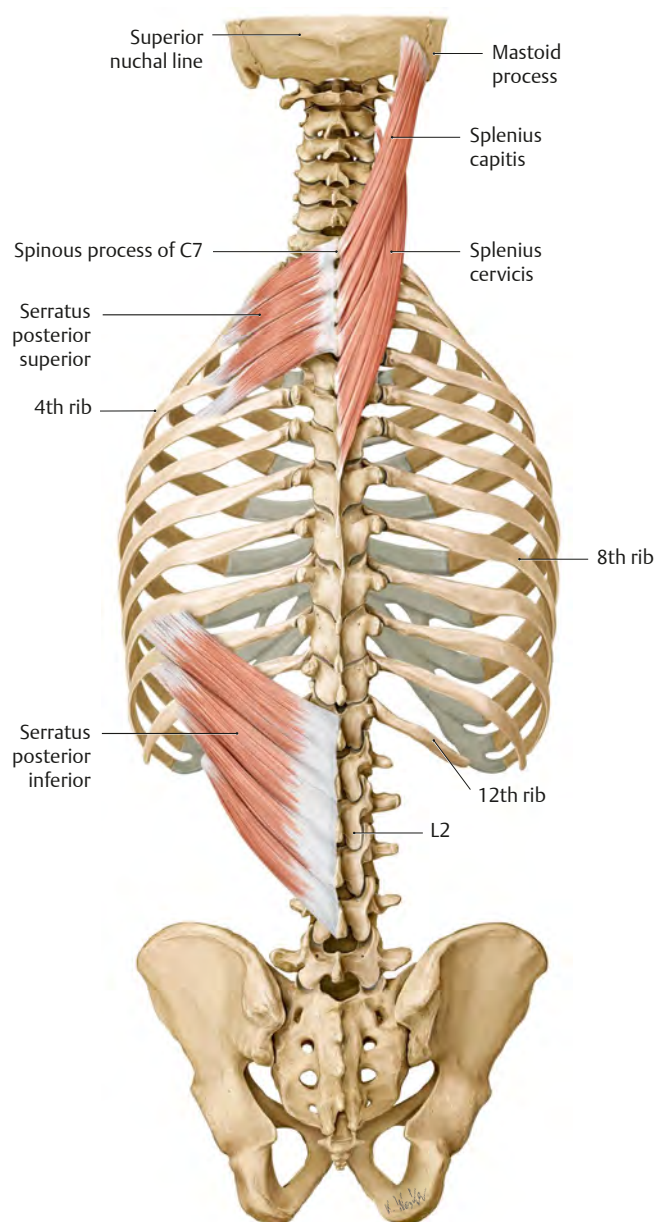
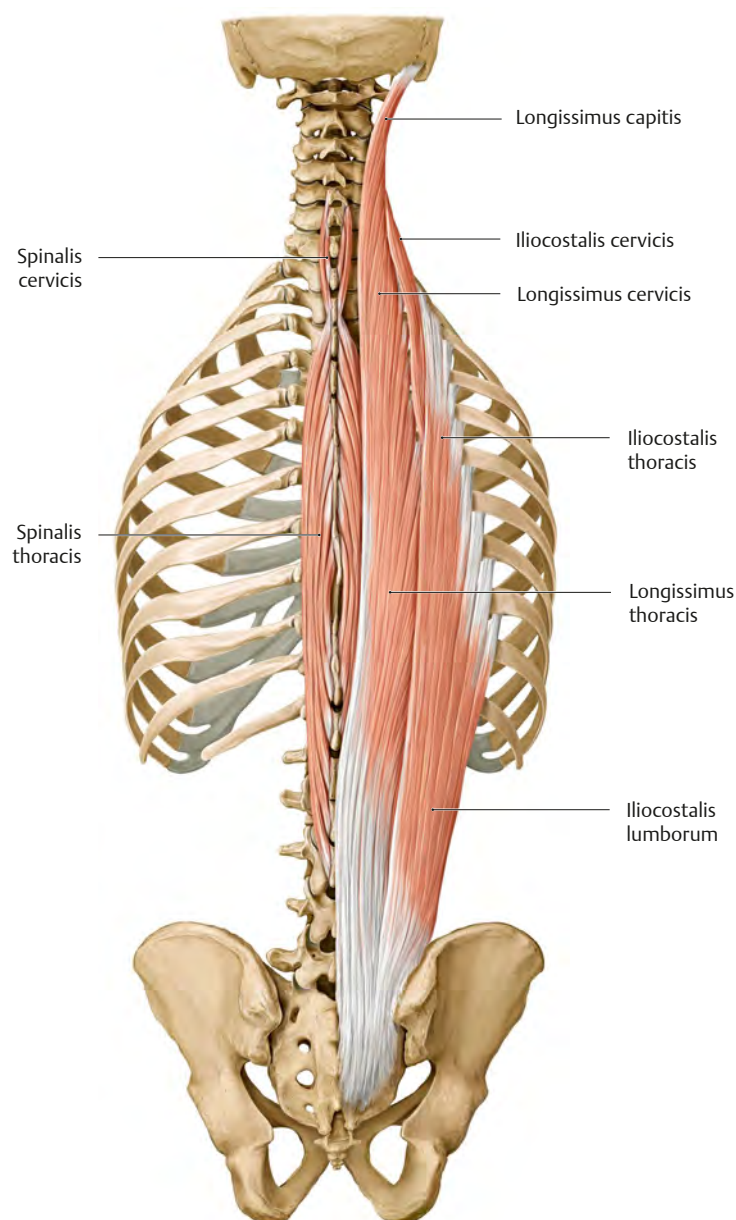


Table 3.4 Intermediate intrinsic back muscles (erector spinae)					
Muscle		Origin	Insertion	Innervation	Action
Iliocostalis	⑤ Iliocostalis cervicis	3rd–7th ribs	C4–C6 (transverse processes)	Spinal nn. C8–L1 (posterior rami, lateral branches)	<i>Bilateral:</i> Extends spine <i>Unilateral:</i> Flexes spine laterally to same side
	⑥ Iliocostalis thoracis	7th–12th ribs	1st–6th ribs		
	⑦ Iliocostalis lumborum	Sacrum; iliac crest; thoracolumbar fascia (posterior layer)	6th–12th ribs; thoracolumbar fascia (posterior layer); upper lumbar vertebrae (transverse processes)		
Longissimus	⑧ Longissimus capitis	T1–T3 (transverse processes); C4–C7 (transverse and articular processes)	Temporal bone (mastoid process)	Spinal nn. C1–L5 (posterior rami, lateral branches)	<i>Bilateral:</i> Extends head <i>Unilateral:</i> Flexes and rotates head to same side
	⑨ Longissimus cervicis	T1–T6 (transverse processes)	C2–C5 (transverse processes)		
	⑩ Longissimus thoracis	Sacrum; iliac crest; lumbar vertebrae (spinous processes); lower thoracic vertebrae (transverse processes)	2nd–12th ribs; thoracic and lumbar vertebrae (transverse processes)		
Spinalis	⑪ Spinalis cervicis	C5–T2 (spinous processes)	C2–C5 (spinous processes)	Spinal nn. (posterior rami)	<i>Bilateral:</i> Extends cervical and thoracic spine <i>Unilateral:</i> Flexes cervical and thoracic spine to same side
	⑫ Spinalis thoracis	T10–L3 (spinous processes, lateral surfaces)	T2–T8 (spinous processes, lateral surfaces)		

Fig. 3.10 Superficial and intermediate intrinsic back muscles
Posterior view.



A Superficial back muscles:
Splenius and serratus posterior muscles.



B Intermediate intrinsic back muscles (erector spinae): Iliocostalis, longissimus, and spinalis muscles.

Muscle Facts (III)

The deep intrinsic back muscles are divided into two groups: transversospinalis and deep segmental muscles. The transversospinalis

muscles pass between the transverse and spinous processes of the vertebrae.

Table 3.5		Transversospinalis muscles			
Muscle		Origin	Insertion	Innervation	Action
Rotatores	① Rotatores breves	T1–T12 (between transverse and spinous processes of adjacent vertebrae)		Spinal nn. (posterior rami)	<i>Bilateral:</i> Extends thoracic spine <i>Unilateral:</i> Rotates thoracic spine to opposite side
	② Rotatores longi	T1–T12 (between transverse and spinous processes, skipping one vertebra)			
Multifidus ③		Sacrum, ilium, mamillary processes of L1–L5, transverse and articular processes of T1–T4, C4–C7	Superomedially to spinous processes, skipping two to four vertebrae		<i>Bilateral:</i> Extends spine <i>Unilateral:</i> Flexes spine to same side, rotates it to opposite side
Semispinalis	④ Semispinalis capitis	C4–T7 (transverse and articular processes)	Occipital bone (between superior and inferior nuchal lines)		<i>Bilateral:</i> Extends thoracic and cervical spines and head (stabilizes craniovertebral joints) <i>Unilateral:</i> Flexes head, cervical and thoracic spines to same side, rotates to opposite side
	⑤ Semispinalis cervicis	T1–T6 (transverse processes)	C2–C5 (spinous processes)		
	⑥ Semispinalis thoracis	T6–T12 (transverse processes)	C6–T4 (spinous processes)		

Fig. 3.11 Transversospinalis muscles

Posterior view, schematic.

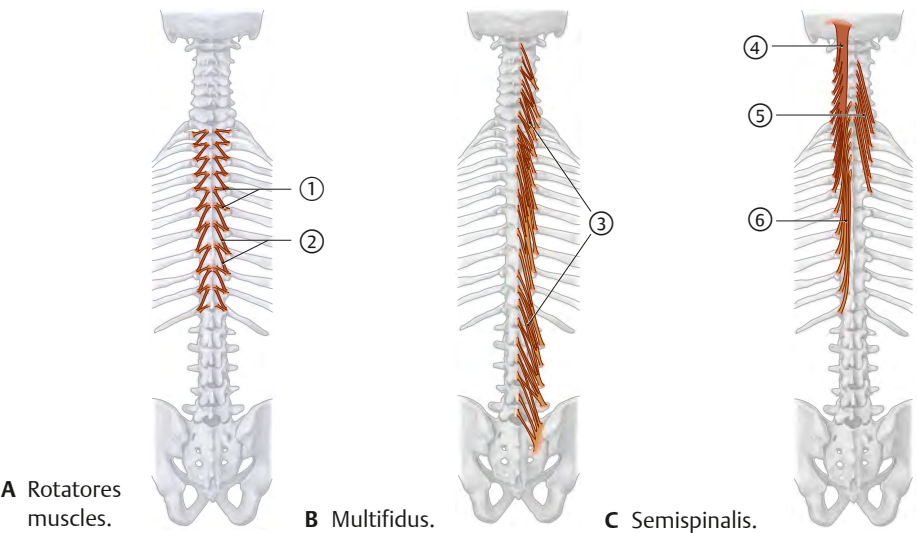


Fig. 3.12 Deep segmental muscles

Posterior view, schematic.

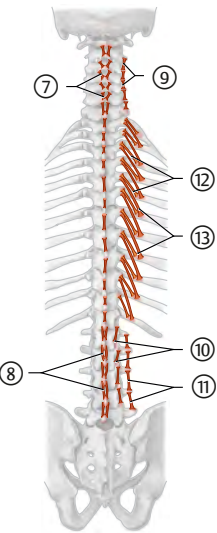
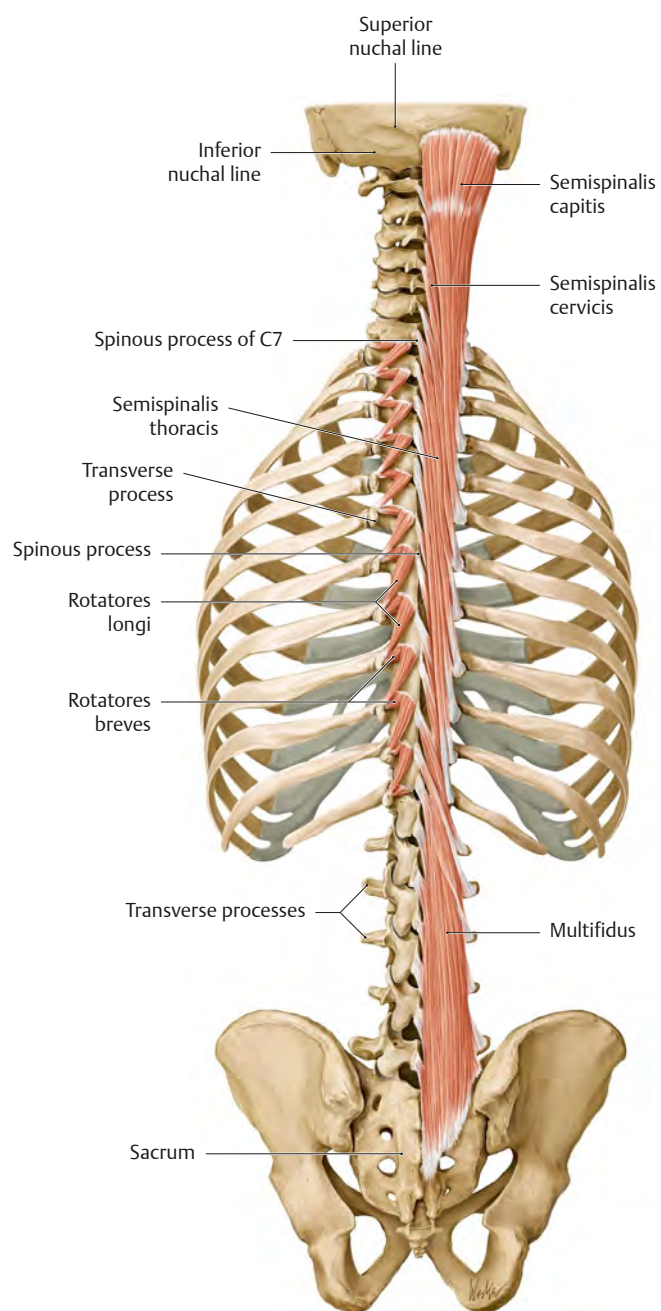
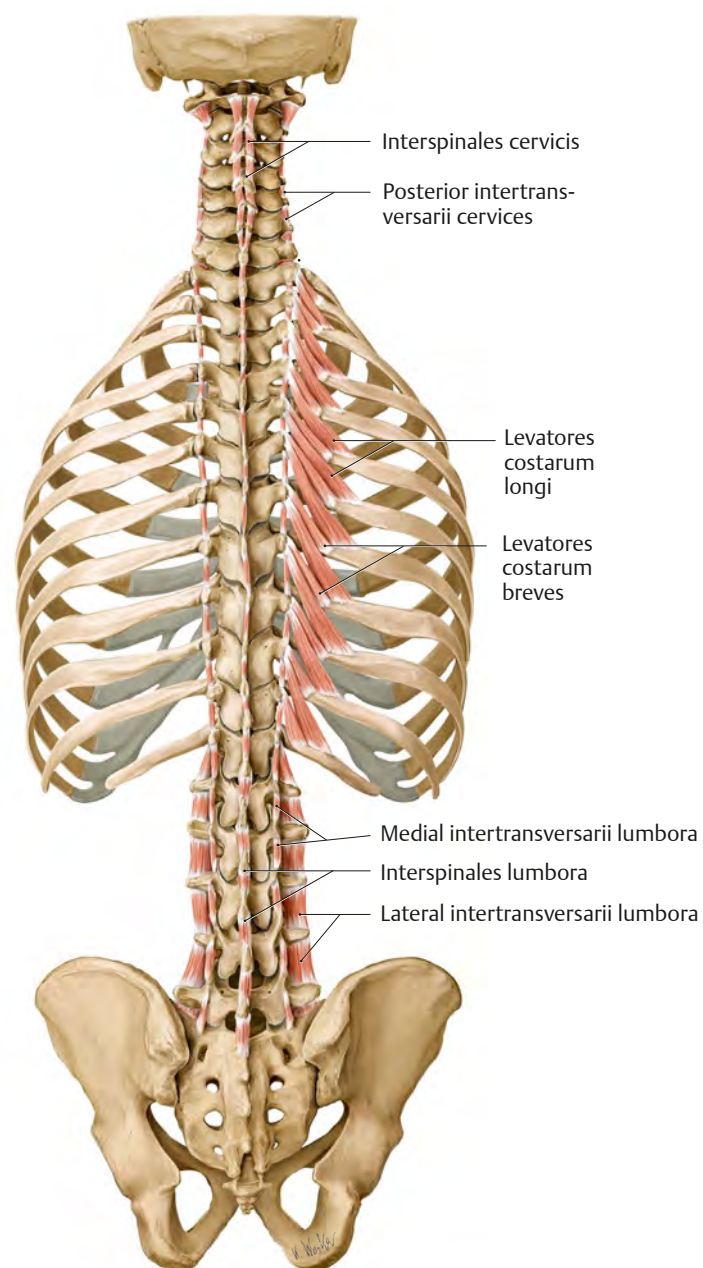


Table 3.6		Deep segmental back muscles			
Muscle		Origin	Insertion	Innervation	Action
Interspinales*	⑦ Interspinales cervicis	C1–C7 (between spinous processes of adjacent vertebrae)		Spinal nn. (posterior rami)	Extends cervical and lumbar spines
	⑧ Interspinales lumbora	L1–L5 (between spinous processes of adjacent vertebrae)			
Intertransversarii*	Anterior intertransversarii cervicis	C2–C7 (between anterior tubercles of adjacent vertebrae)		Spinal nn. (anterior rami)	<i>Bilateral:</i> Stabilizes and extends the cervical and lumbar spines <i>Unilateral:</i> Flexes the cervical and lumbar spines laterally to same side
	⑨ Posterior intertransversarii cervicis	C2–C7 (between posterior tubercles of adjacent vertebrae)		Spinal nn. (posterior rami)	
	⑩ Medial intertransversarii lumbora	L1–L5 (between mamillary processes of adjacent vertebrae)		Spinal nn. (posterior rami)	
	⑪ Lateral intertransversarii lumbora	L1–L5 (between transverse processes of adjacent vertebrae)		Spinal nn. (anterior rami)	
Levatores costarum	⑫ Levatores costarum breves		Costal angle of next lower rib	Spinal nn. (posterior rami)	<i>Bilateral:</i> Extends thoracic spine <i>Unilateral:</i> Flexes thoracic spine to same side, rotates to opposite side
	⑬ Levatores costarum longi	C7–T11 (transverse processes)	Costal angle of rib two vertebrae below		

*Both the interspinales and intertransversarii muscles traverse the entire spine; only their clinically relevant components have been included.

Fig. 3.13 Deep intrinsic back muscles

Posterior view.

**A** Transversospinalis muscles: Rotatores, multifidus, and semispinalis.**B** Deep segmental muscles: Interspinales, intertransversarii, and levatores costarum.

4 Neurovasculature

Arteries & Veins of the Back

Fig. 4.1 Arteries of the back

The structures of the back are supplied by branches of the posterior intercostal arteries, which arise from the thoracic aorta or from the subclavian artery.

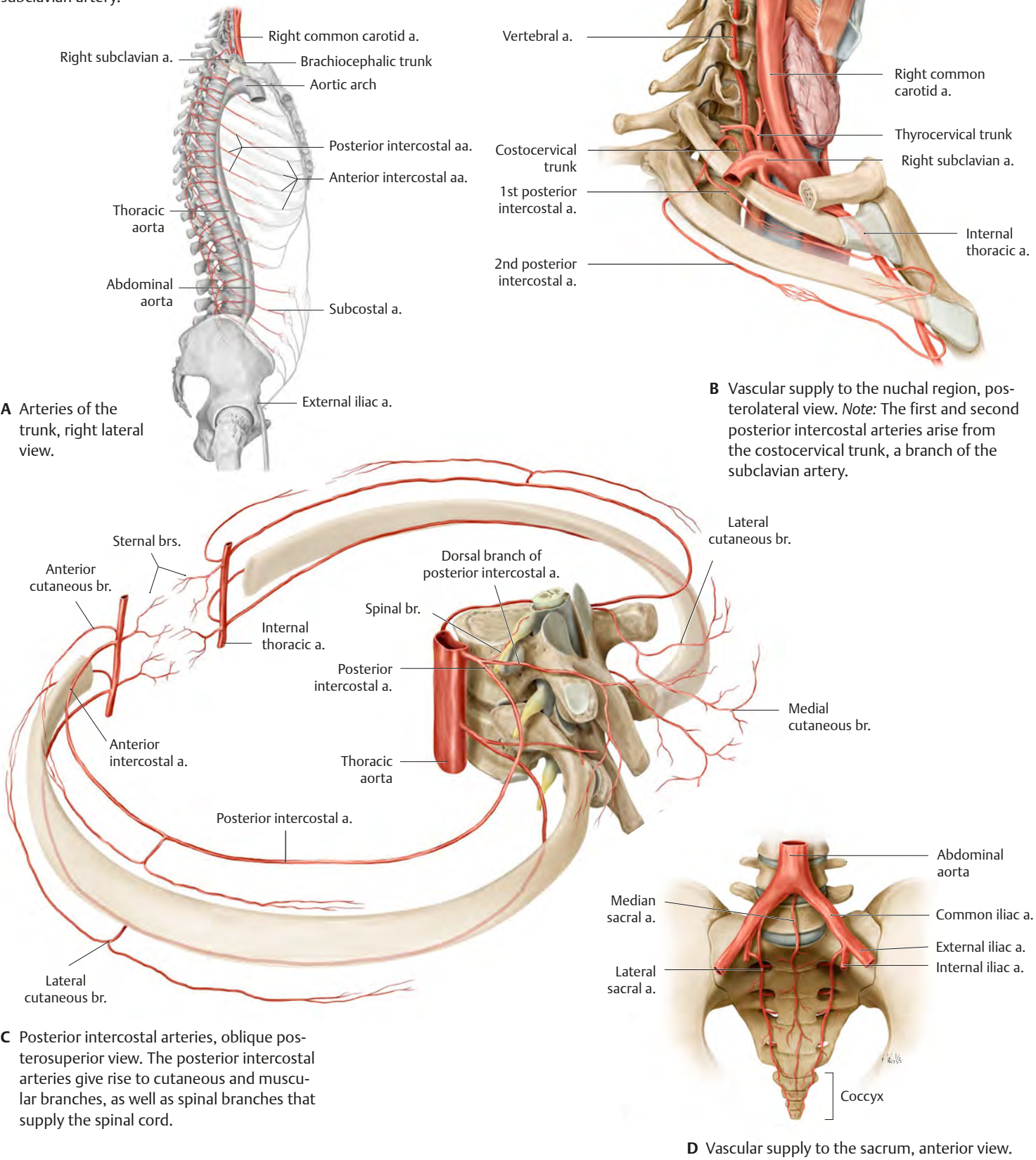
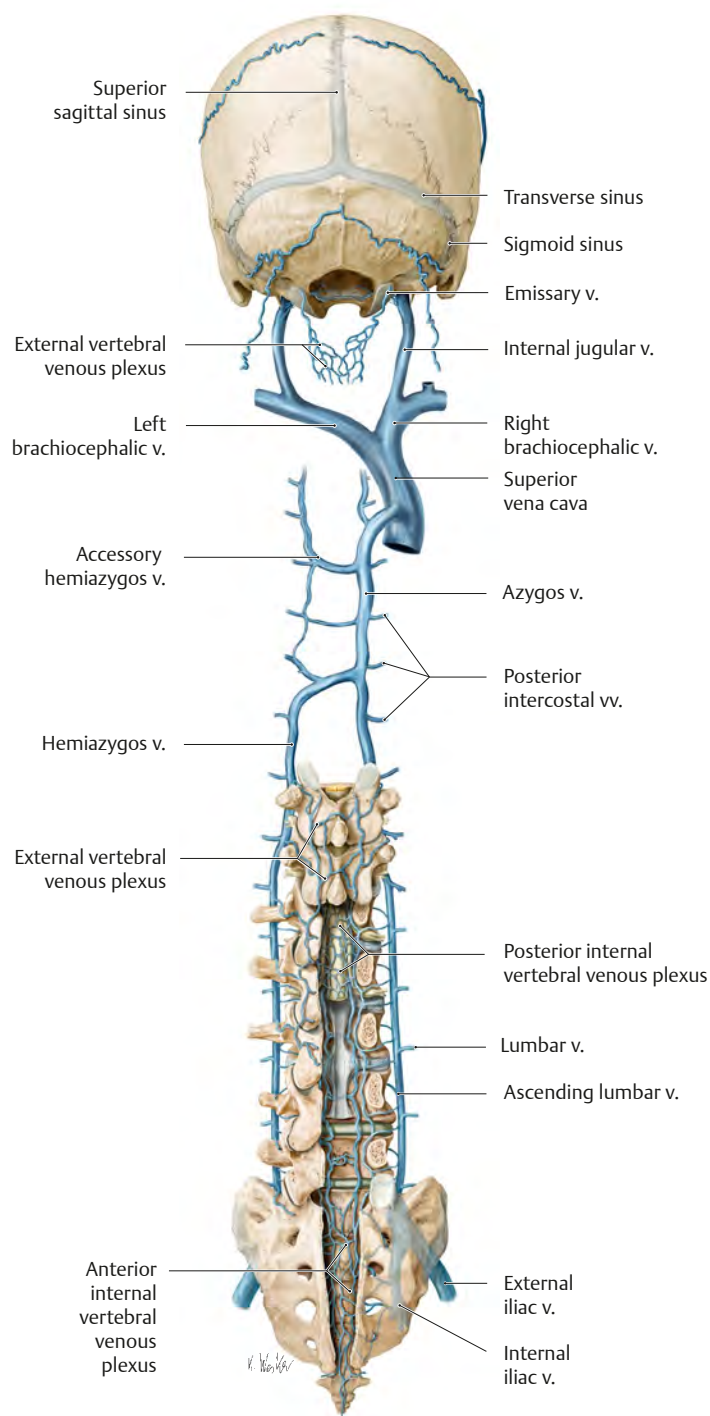
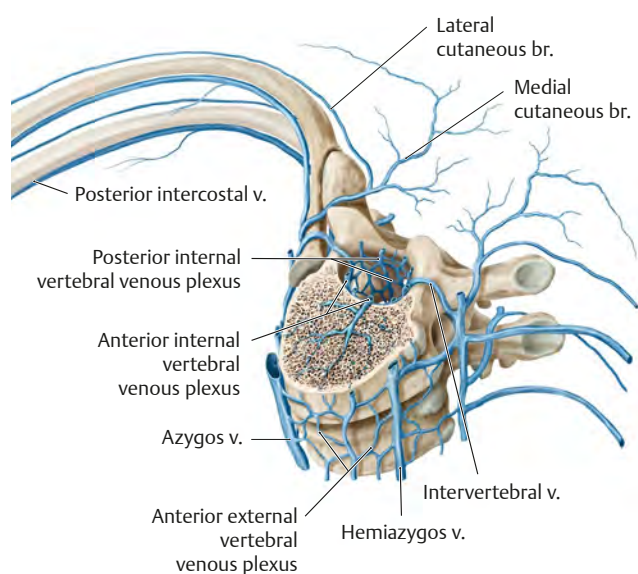
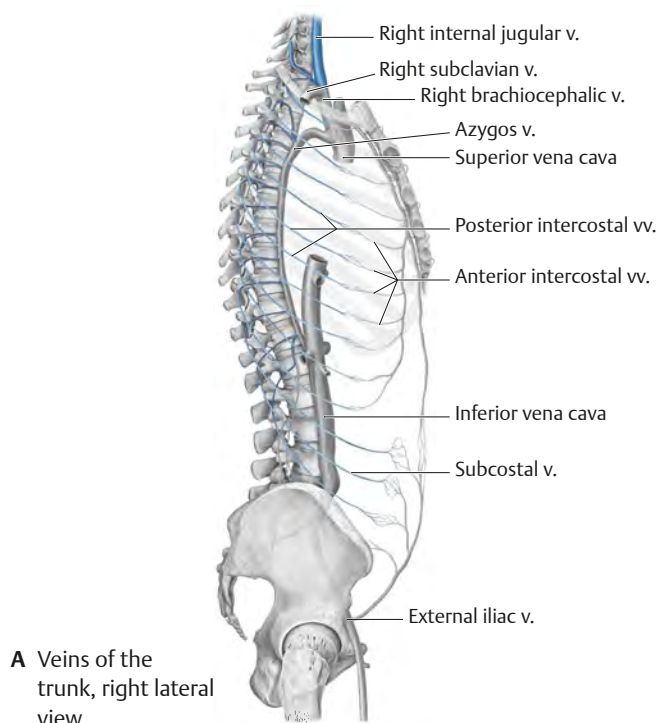


Fig. 4.2 Veins of the back

The veins of the back drain into the azygos vein via the posterior intercostal veins, hemiazygos vein, and ascending lumbar veins. The interior of the spinal column is drained by the vertebral venous plexus that runs the length of the spine.



Nerves of the Back

The back receives its innervation from branches of the spinal nerves. The *posterior (dorsal) rami* of the spinal nerves supply most of the intrinsic

muscles of the back. The extrinsic muscles of the back are supplied by the *anterior (ventral) rami* of the spinal nerves.

Fig. 4.3 Nerves of the back

Cross section of the vertebral column and spinal cord with surrounding musculature, superior view.

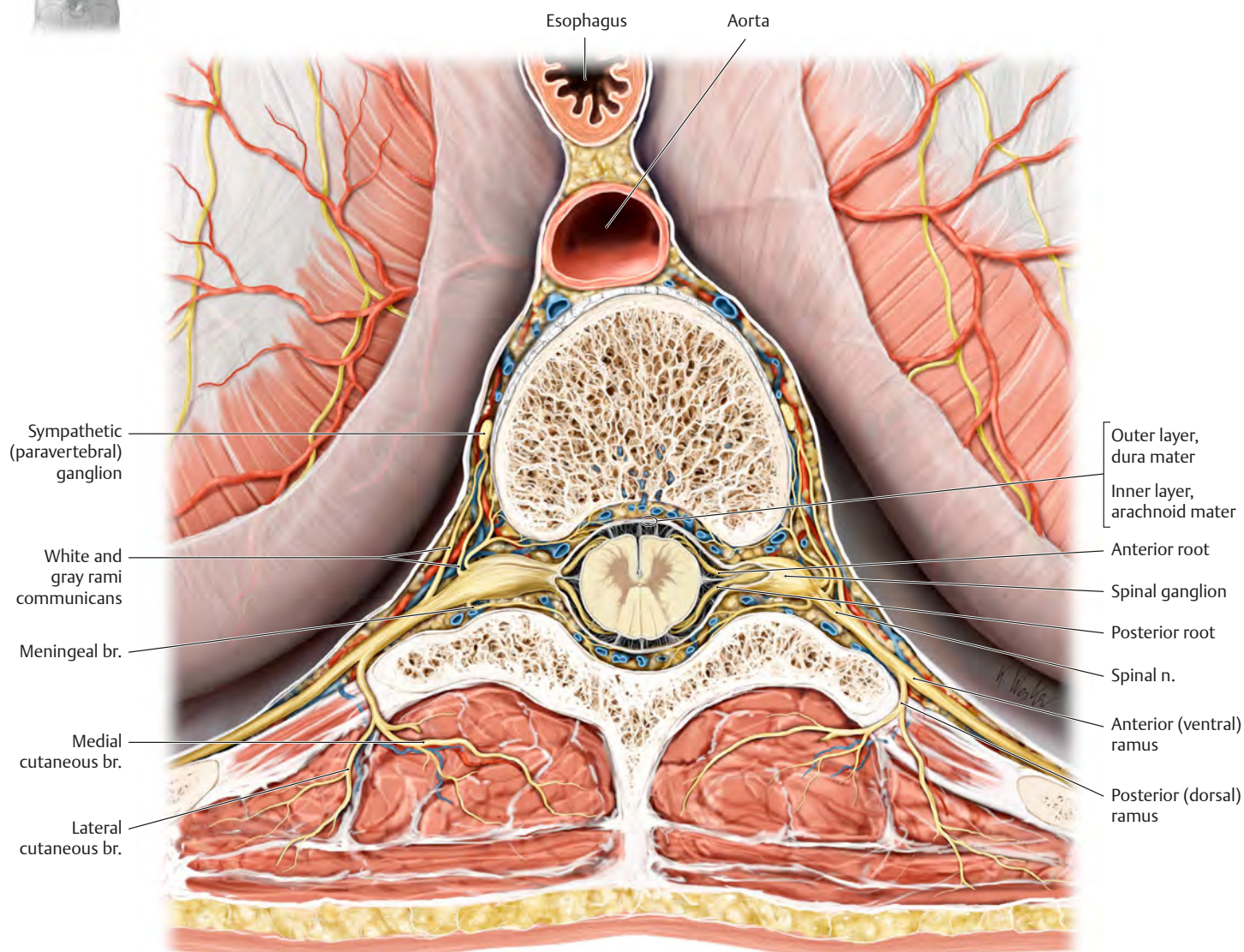
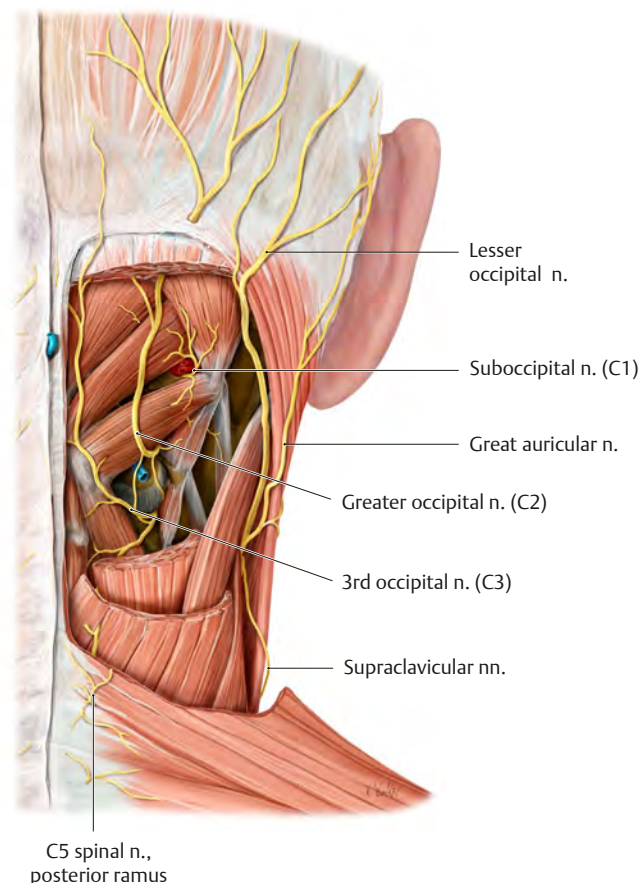


Fig. 4.4 Nerves of the nuchal region

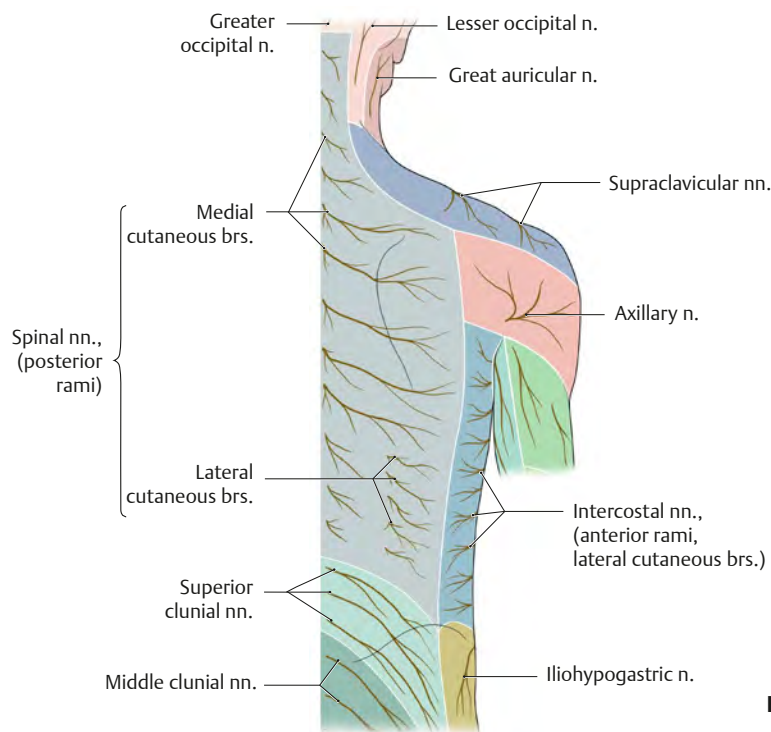
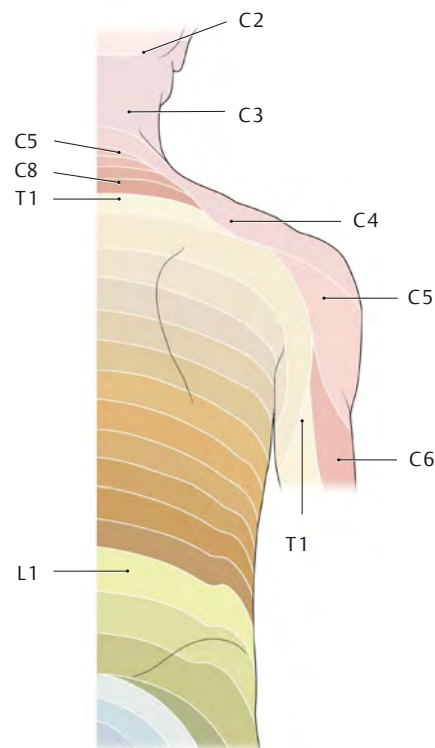
Right side, posterior view.

Table 4.1 Nerves of the nuchal region		
Branches		Function
Posterior (dorsal) ramus	Suboccipital n. (C1)	Innervates the rectus capitis posterior major and minor; and obliquus capitis superior and inferior
	Greater occipital n. (C2)	Assists in the innervation of the semispinalis capitis muscle and supplies skin behind the auricle and the scalp to the coronal suture
	Third occipital n. (C3)	Assists in the innervation of the semispinalis capitis muscle, the C2-C3 facet joint, and supplies a small area of skin just below the superior nuchal line
Anterior (ventral) ramus	Lesser occipital n. (C2)	Cutaneous only, supplies an area of scalp posterolateral to the auricle, and the skin on the upper third of the medial aspect of the auricle
	Greater auricular n. (C2, C3)	Cutaneous only, supplies an area of skin over the parotid gland, the majority of the pinna, lateral neck, and posterior to the auricle

****The anterior rami of C1-C3 also give rise to the ansa cervicalis, which innervates the infrahyoid muscles (see p. 524).**

**Fig. 4.5 Cutaneous innervation of the back**

Color denotes the skin areas innervated by (A) particular peripheral nerves or (B) particular pairs of segmental spinal nerves. Patterns of loss of cutaneous sensation can be helpful in diagnosis of nerve lesions.

**A** Cutaneous innervation patterns of specific peripheral nerves.**B** Dermatomes: Dermatomes are bilateral band-like areas of skin receiving innervation from a single pair of spinal nerves (from a single segment of the spinal cord). Note: Spinal nerve C1 is purely motor; consequently there is no C1 dermatome.

Spinal Cord

The dura mater of the cranial cavity is composed of two layers, the periosteal and meningeal. Only the meningeal layer extends into the vertebral canal with the spinal cord. The periosteal layer of dura

Fig. 4.6 Spinal cord in situ
Posterior view with vertebral canal windowed.

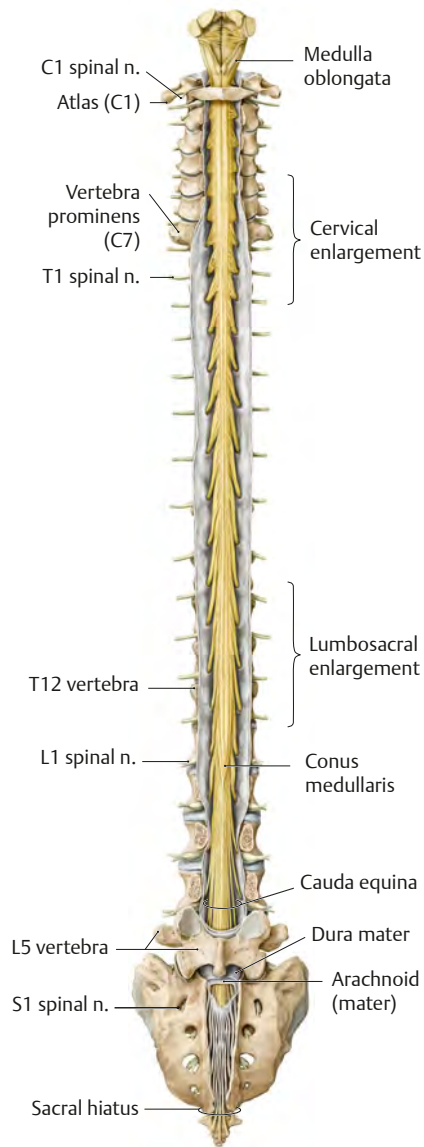


Fig. 4.7 Spinal cord and its meningeal layers
Posterior view. The dura mater is opened and the arachnoid is sectioned. The detailed anatomy of the spinal cord can be found on pp. 690–691.

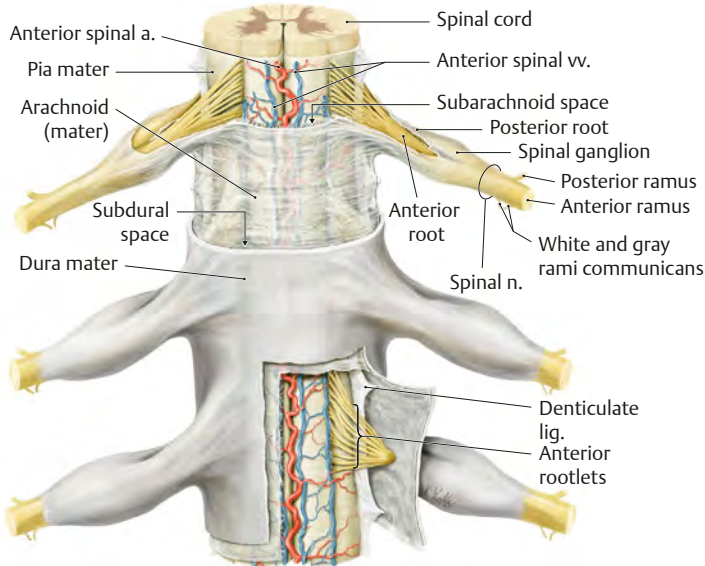
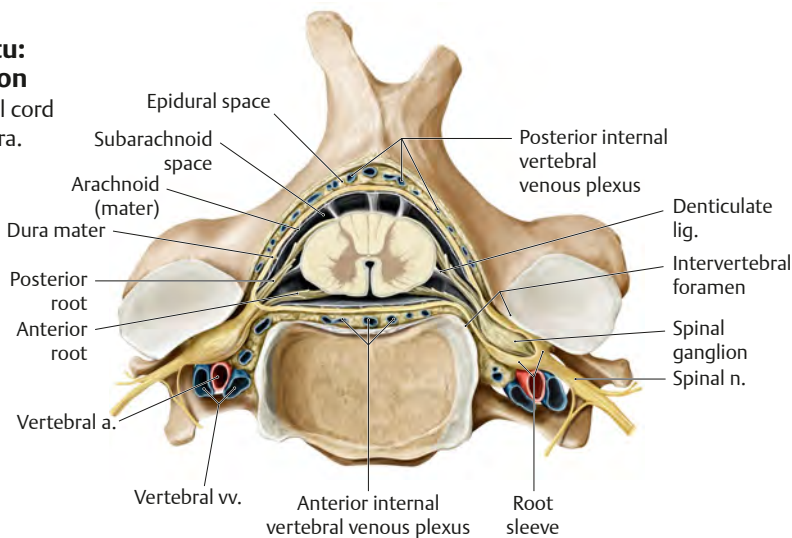


Fig. 4.8 Cervical spinal cord in situ: Transverse section
Superior view. Spinal cord at level of C4 vertebra.



Clinical box 4.1

Spina Bifida

Spina bifida is a neural tube defect that occurs when the spine and spinal cord do not form properly. In the United States, it affects about one out of every 1,500 newborns. There are three main types.

- **Spina bifida occulta (A)** is the most common congenital anomaly of the vertebral column in which the laminae of L5 and/or S1 fail to develop. The defect is often hidden and most individuals are unaware they have the condition because there is only a small defect in the vertebrae. There is generally no disturbance of spinal function.
- **Spina bifida (meningocele) (B)** occurs when one or more vertebral arches fail to develop and presents with a herniation or sac of only the meninges. The spinal cord and nerves are normal and not severely affected.

- **Spina bifida (myelomeningocele) (C)** occurs when multiple vertebral arches fail to develop resulting in a herniation of both the meninges and spinal nerves. This is the most severe form exposing the newborn to life threatening infections, bowel and bladder dysfunction, and total paralysis of the lower extremities.

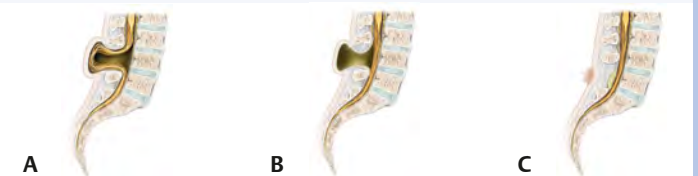
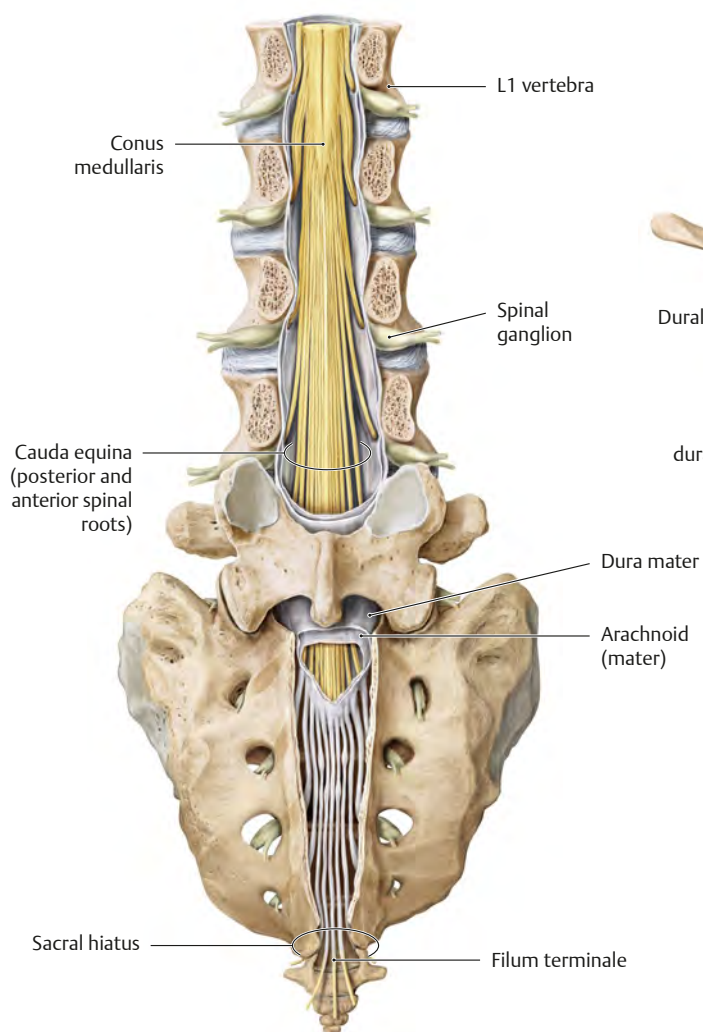
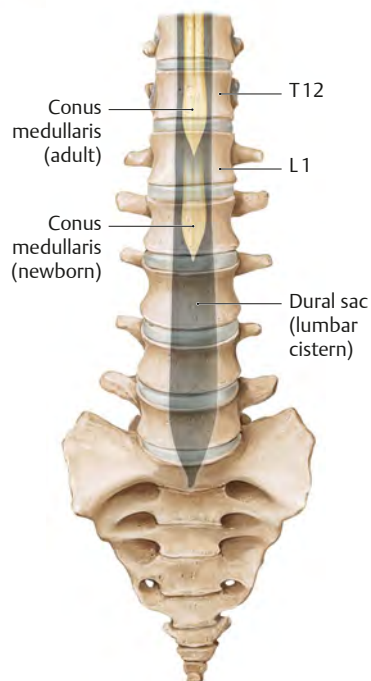


Fig. 4.9 Cauda equina in the vertebral canal

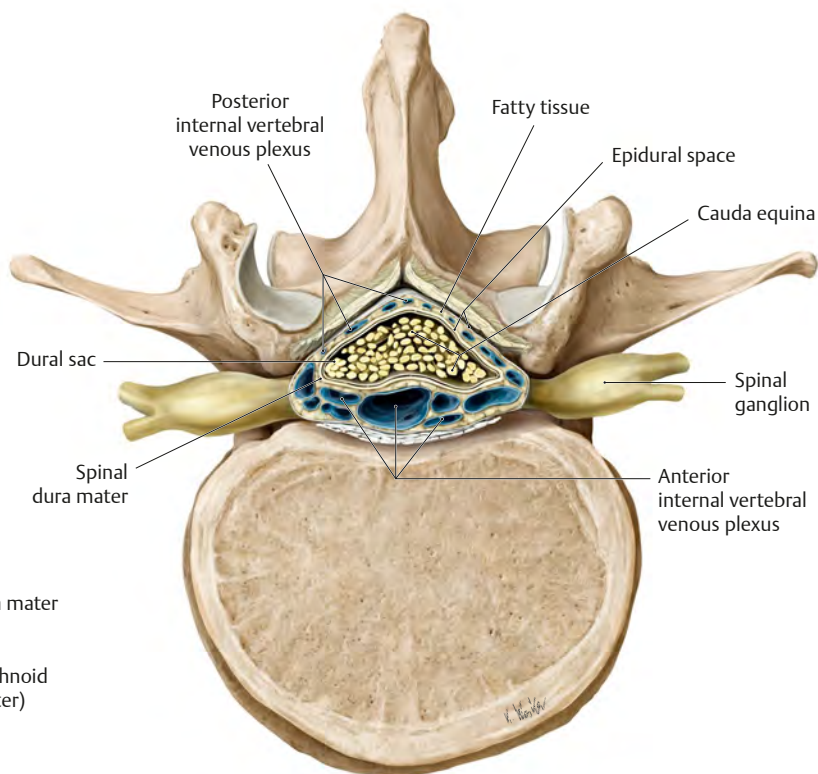
Posterior view. The lamina and posterior surface of the sacrum have been partially removed.

**Fig. 4.11 Spinal cord, dural sac, and vertebral column at different ages.**

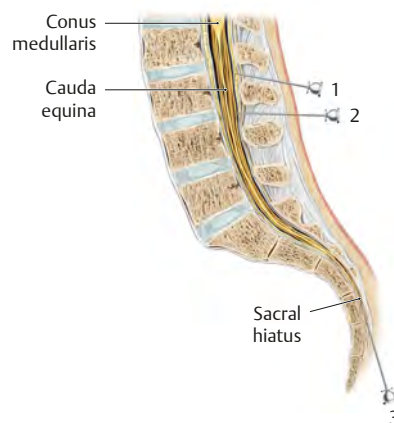
Anterior view. Longitudinal growth of the spinal cord lags behind that of the vertebral column. At birth, the distal end of the spinal cord, the conus medullaris, is at the level of the L3 vertebral body, but in the average adult it extends to the level of L1/L2. The dural sac always extends into the upper sacrum.

**Fig. 4.10 Cauda equina in situ: Transverse section**

Superior view. Cauda equina at level of L2 vertebra.

**Clinical box 4.2****Lumbar puncture**

A needle introduced into the dural sac (lumbar cistern) generally slips past the spinal nerve roots without injuring the spinal cord or spinal nerves. Cerebrospinal fluid (CSF) samples are therefore taken between the L3 and L4 vertebrae (2), once the patient has leaned forward to separate the spinous processes of the lumbar spine.

**Anesthesia**

Lumbar anesthesia may be administered in a similar fashion (2). Epidural anesthesia is administered by placing a catheter in the epidural space without penetrating the dural sac (1). This may also be done by passing a needle through the sacral hiatus (3).

Spinal Cord Segments & Spinal Nerves

Fig. 4.12 Spinal cord segment

The spinal cord consists of 31 segments, each innervating a specific area of the skin (a dermatome) of the head, trunk, or limbs. Afferent (sensory) posterior rootlets and efferent (motor) anterior rootlets form the posterior and anterior roots of the spinal nerve for that segment. The two roots fuse to form a mixed (motor and sensory) spinal nerve that exits the intervertebral foramen and immediately thereafter divides into an anterior and posterior ramus.

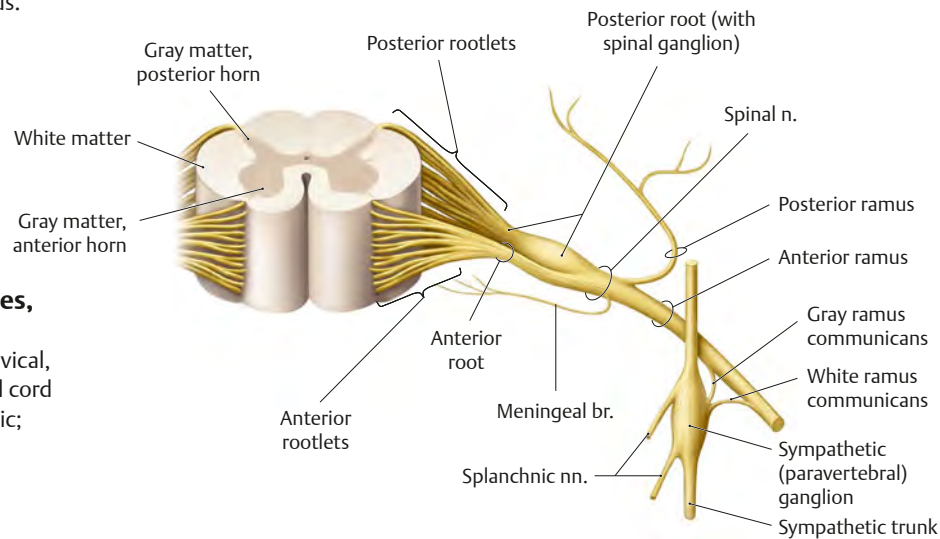
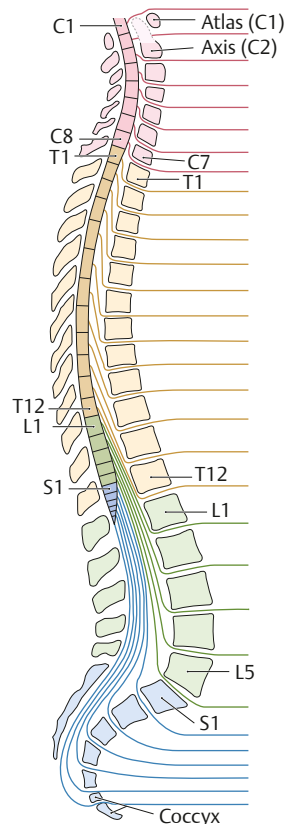


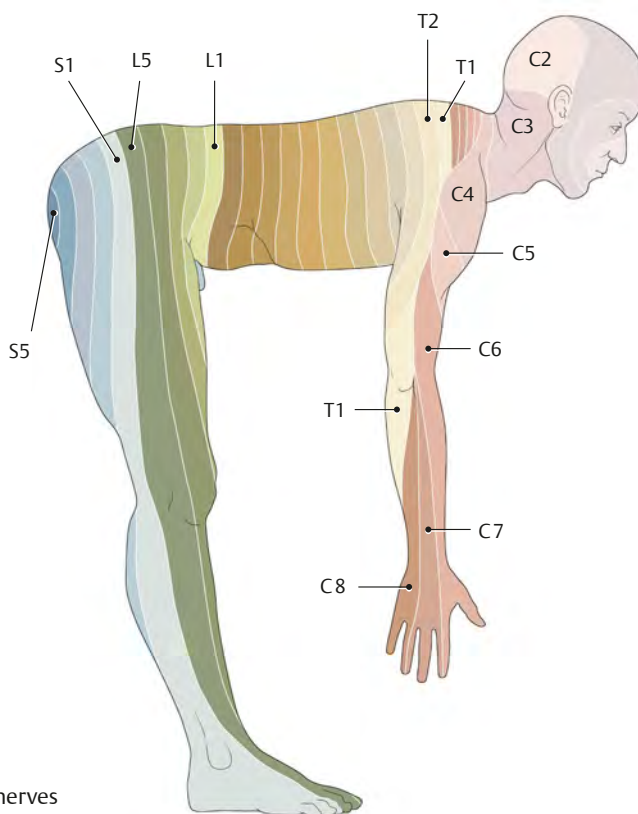
Fig. 4.13 Spinal cord segments, dermatomes, and effects of spinal cord lesions

The spinal cord is divided into four major regions: cervical, thoracic, lumbar, and sacral. The regions of the spinal cord are designated by colors: red, cervical; brown, thoracic; green, lumbar; blue, sacral.

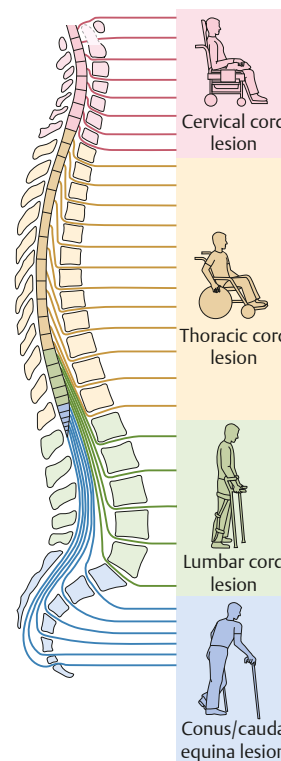
Spinal cord segment Vertebra



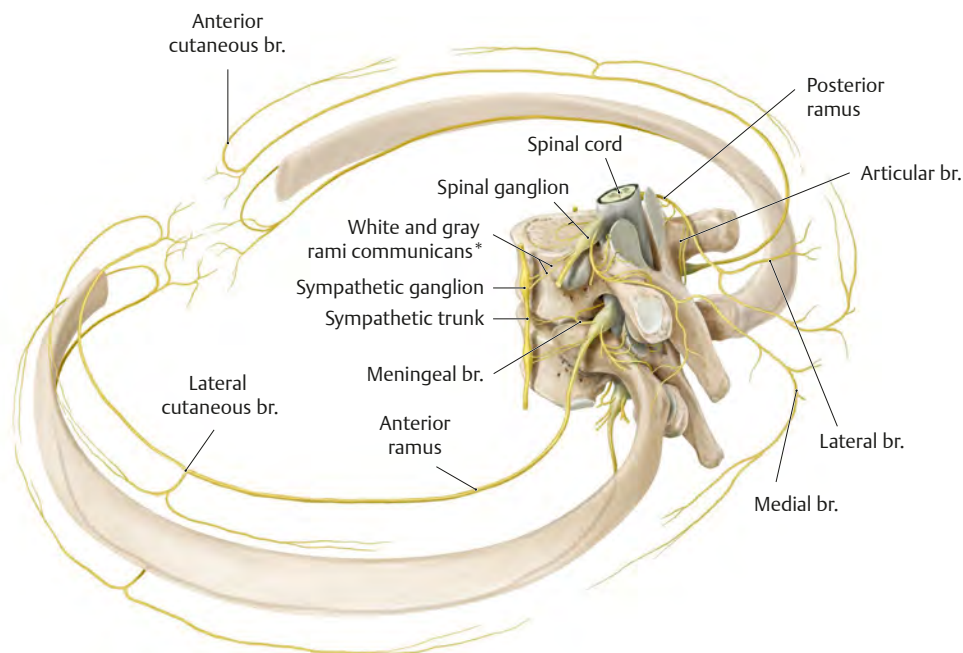
A Spinal cord segments. Initially spinal nerves pass out above the vertebrae for which they are numbered. However, since there is an 8th cervical spinal nerve but no 8th cervical vertebrae, C8 passes out above vertebral level T1, and the spinal nerve for T1, and those following, pass out below the vertebral level for which they are numbered.



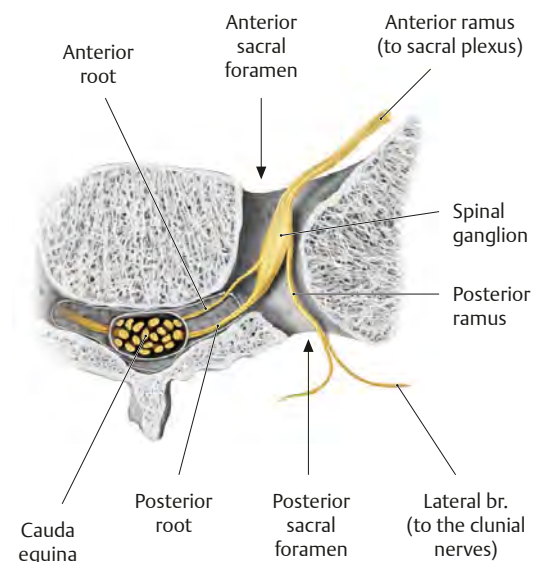
B Dermatomes, band-like areas of skin receiving sensory innervation from a single pair of spinal nerves (from a single segment of the spinal cord). *Note:* Spinal nerve C1 is purely motor; consequently there is no C1 dermatome.



C Effects of lesions in each region of the spinal cord.

Fig. 4.14 Spinal nerve branches

A Superolateral view of a thoracic spinal nerve. The *posterior (dorsal) rami* of the spinal nerves give rise to muscular and cutaneous branches, as well as articular branches to the zygapophyseal joints. The *anterior (ventral) rami* of the spinal nerves form the cervical plexus (C1–C4), the brachial plexus (C5–T1), the lumbar plexus (T12–L4), and the sacral plexus (L4–S3). The anterior rami of spinal nerves T1–T11 produce the intercostal nerves (T12 produces the subcostal nerve).



B Spinal nerve branches in the sacral foramina. Superior view of transverse section through right half of sacrum.

Table 4.2				Branches of a spinal nerve	
Branches			Territory		
Meningeal br.			Spinal meninges; ligaments of spinal column		
Posterior (dorsal) ramus	Medial brs.	Articular br.	Zygapophyseal joints		
		Muscular br.	Intrinsic back muscles		
		Cutaneous br.	Skin of posterior head, neck, back, and buttocks		
	Lateral brs.	Cutaneous br.	Skin of posterior head, neck, back, and buttocks		
		Muscular br.	Intrinsic back muscles		
Anterior (ventral) ramus	Lateral cutaneous brs.		Skin of lateral chest wall		
	Anterior cutaneous brs.		Skin of anterior chest wall		
*The white and gray rami communicans carry pre- and postganglionic fibers between the sympathetic trunk and spinal nerve.					

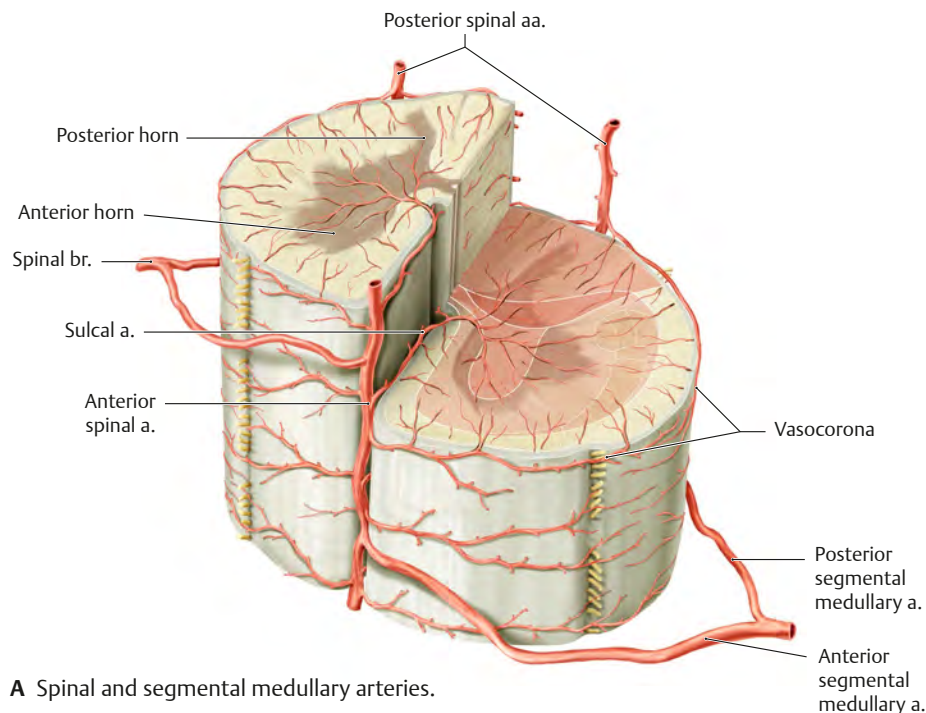
Arteries & Veins of the Spinal Cord

Back

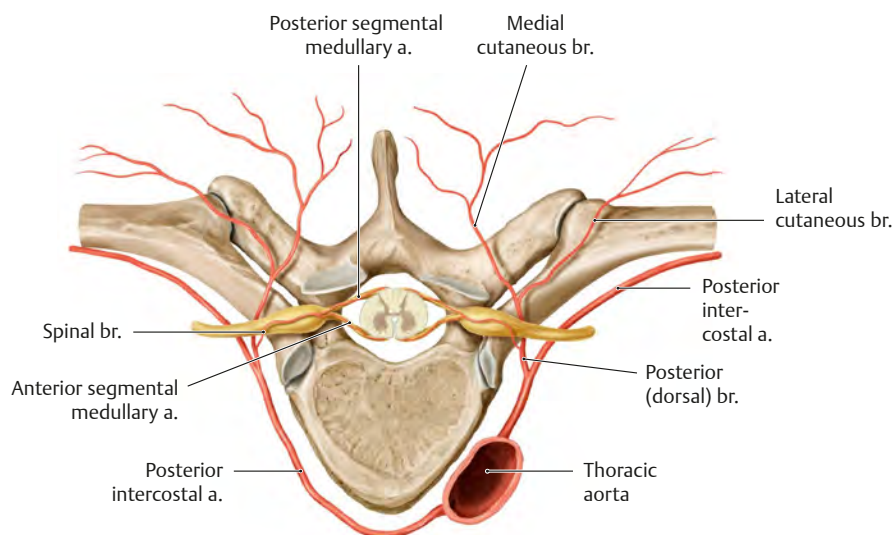
Like the spinal cord itself, the arteries and veins of the spinal cord consist of multiple horizontal systems (blood vessels of the spinal cord segments) that are integrated into a vertical system.

Fig. 4.15 Arteries of the spinal cord

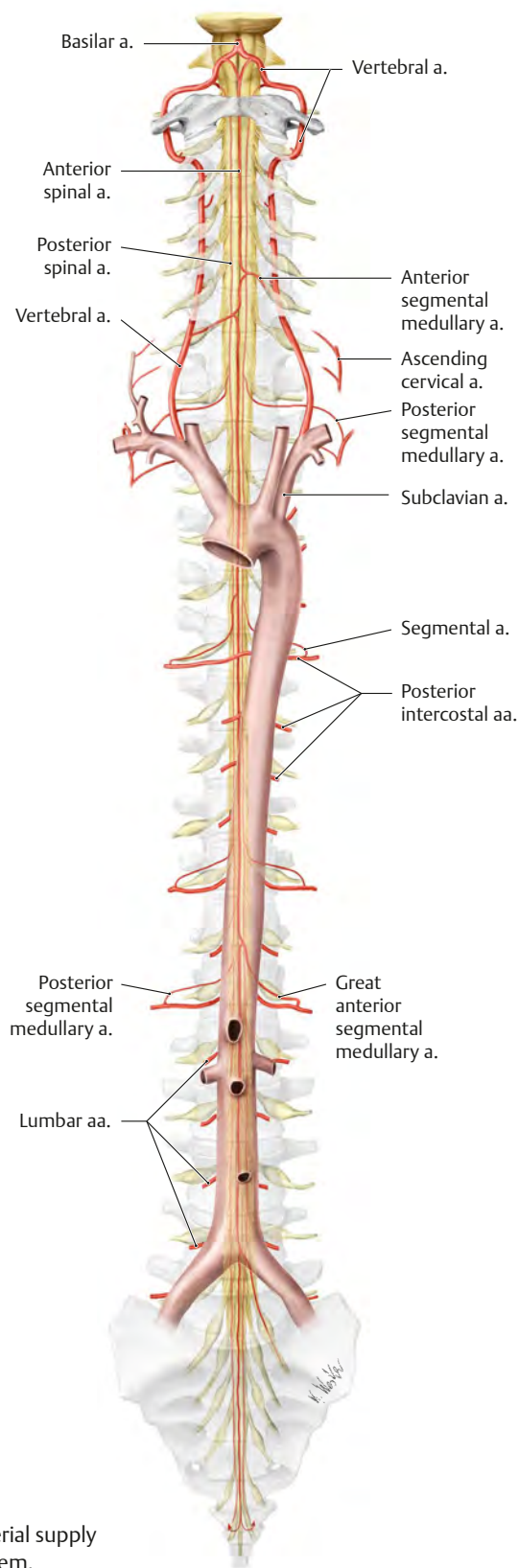
The unpaired anterior and paired posterior spinal arteries typically arise from the vertebral arteries. As they descend within the vertebral canal, the spinal arteries are reinforced by anterior and posterior segmental medullary arteries. Depending on the spinal level, these reinforcing branches may arise from the vertebral, ascending or deep cervical, posterior intercostal, lumbar, or lateral sacral arteries.



A Spinal and segmental medullary arteries.



B Origins of the segmental medullary arteries. In the thorax, the segmental medullary arteries arise from the spinal branch of the posterior intercostal arteries (see p. 36).



C Arterial supply system.

Fig. 4.16 Veins of the spinal cord

The interior of the spinal cord drains via venous plexuses into an anterior and a posterior spinal vein. The radicular and spinal veins connect the veins of the spinal cord with the internal vertebral venous plexus. The intervertebral and basivertebral veins connect the internal and external venous plexuses, which drain into the azygos system.

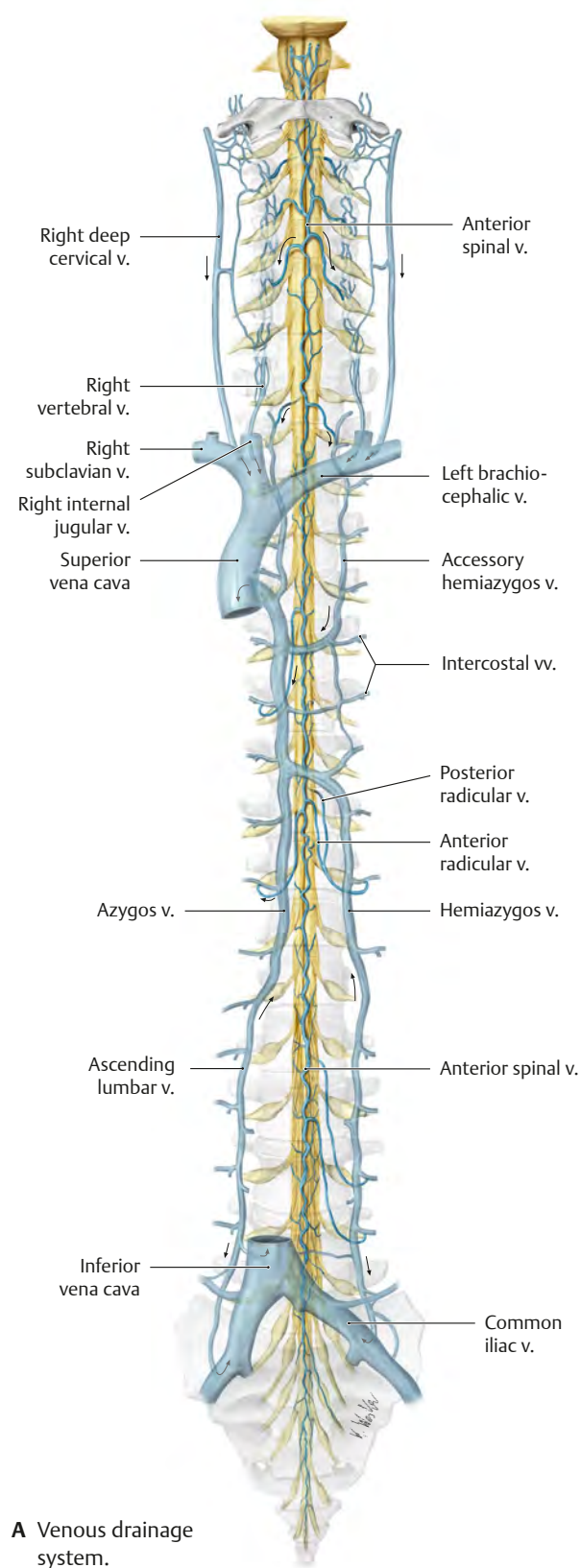
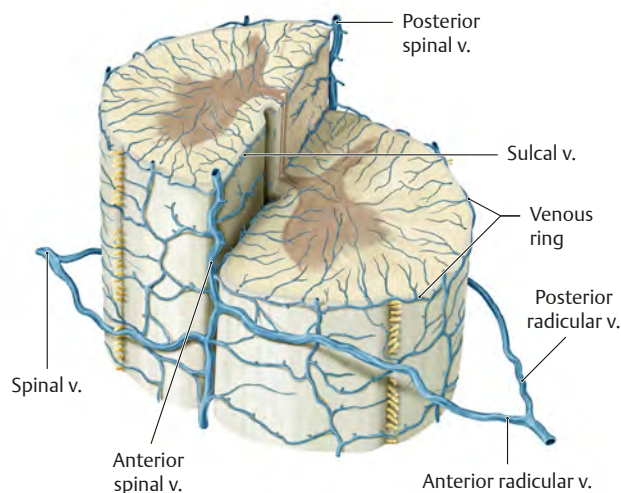
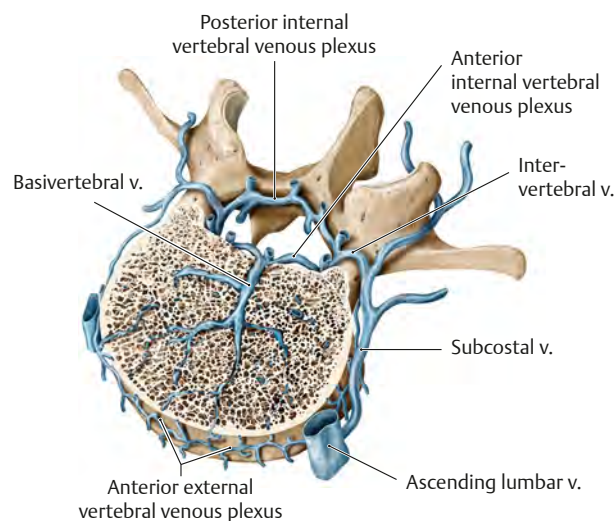
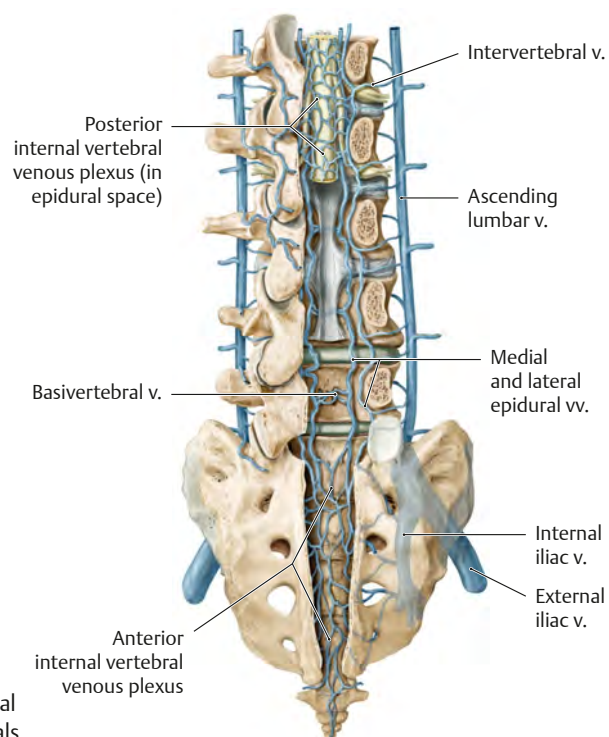
**B Spinal and radicular veins.****C Vertebral venous plexuses.****D Veins in the sacral and lumbar canals.**

Fig. 4.17 Neurovasculature of the nuchal region

Posterior view. *Removed:* Trapezius, sternocleidomastoid, and semispinalis capitis.

Revealed: Suboccipital region.

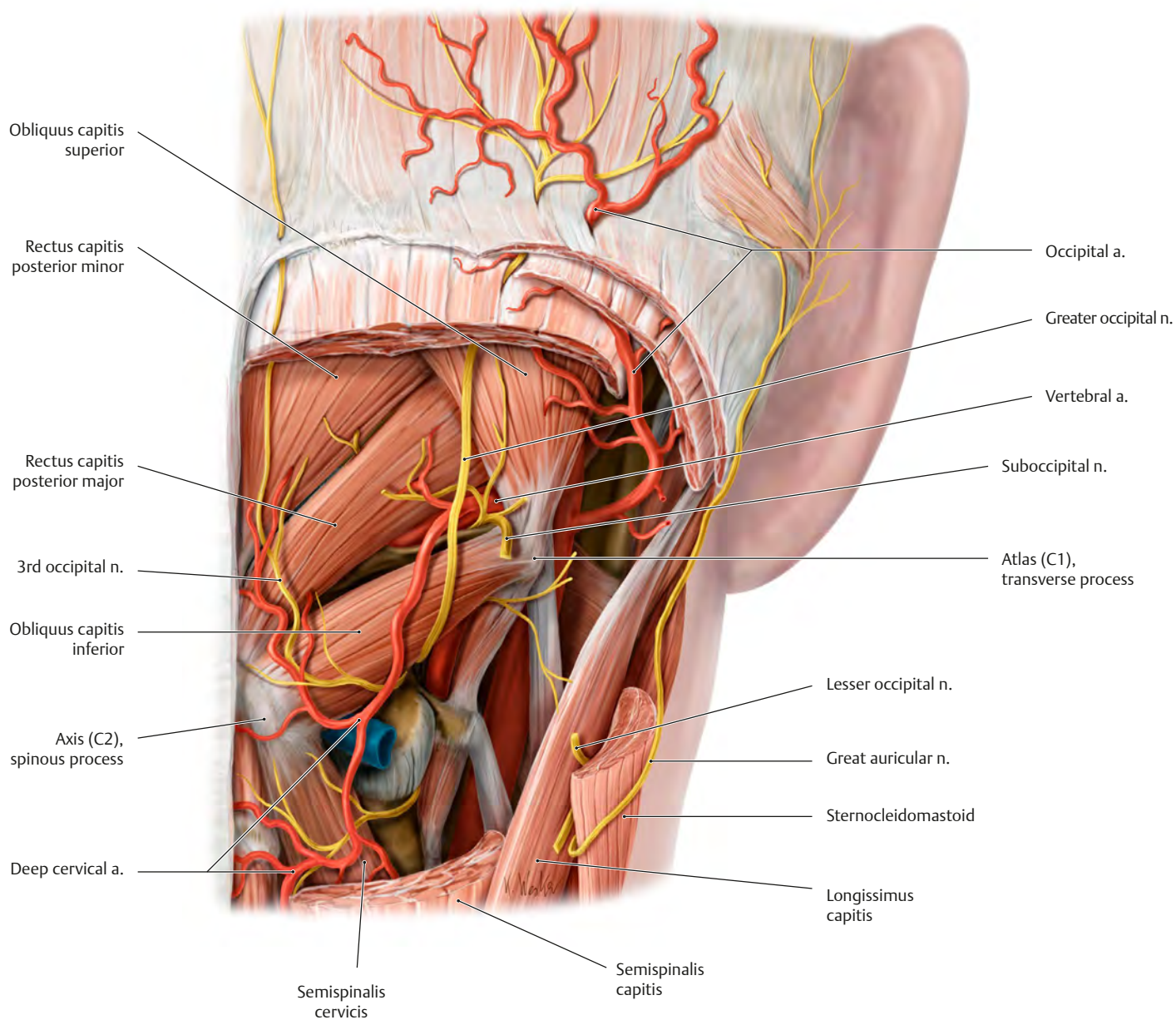
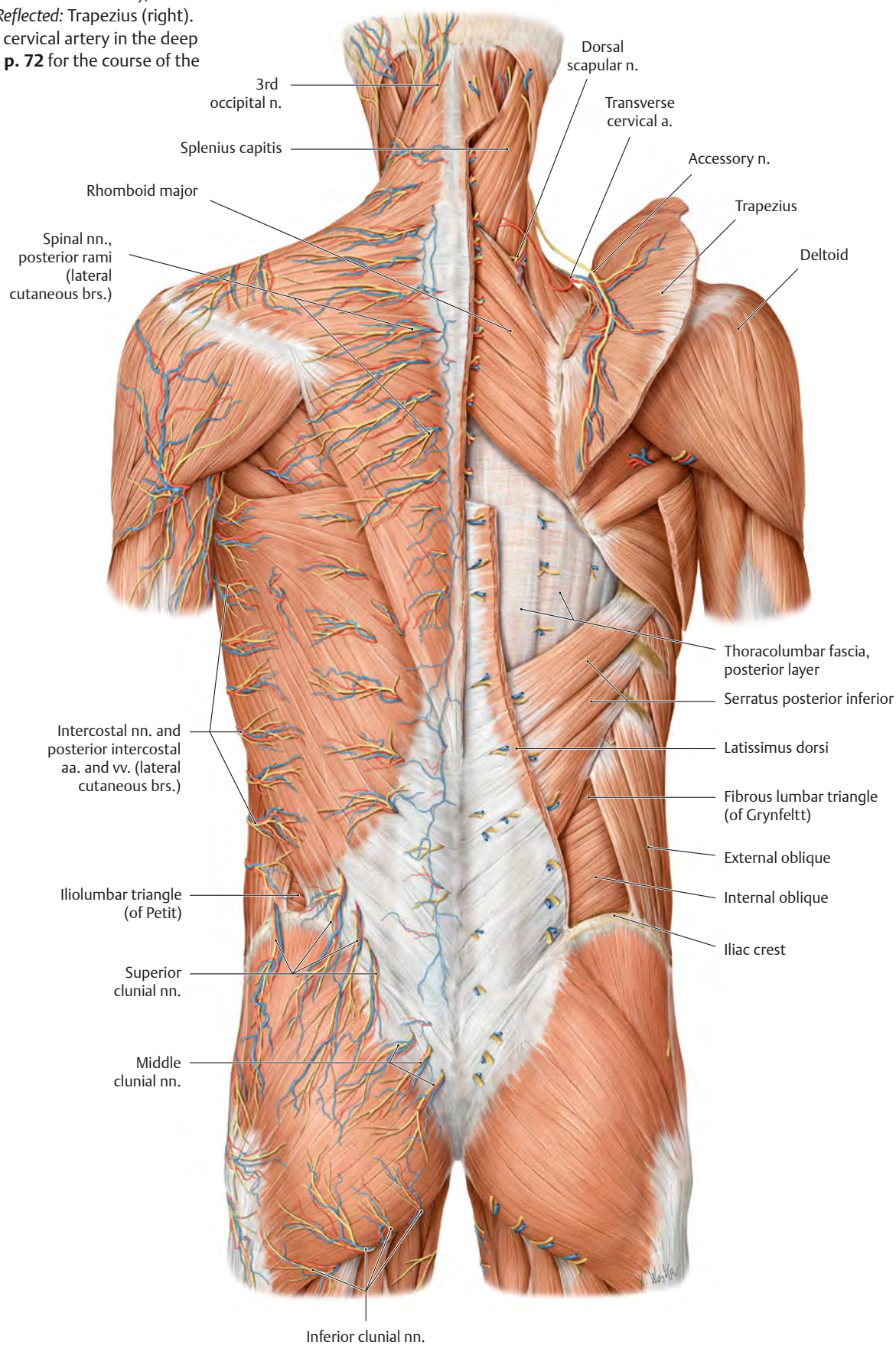


Fig. 4.18 Neurovasculature of the back

Posterior view. *Removed:* Muscle fascia (except posterior layer of thoracolumbar fascia); latissimus dorsi (right). *Reflected:* Trapezius (right). *Revealed:* Transverse cervical artery in the deep scapular region. See p. 72 for the course of the intercostal vessels.



5 Sectional & Radiographic Anatomy

Radiographic Anatomy of the Back (I)

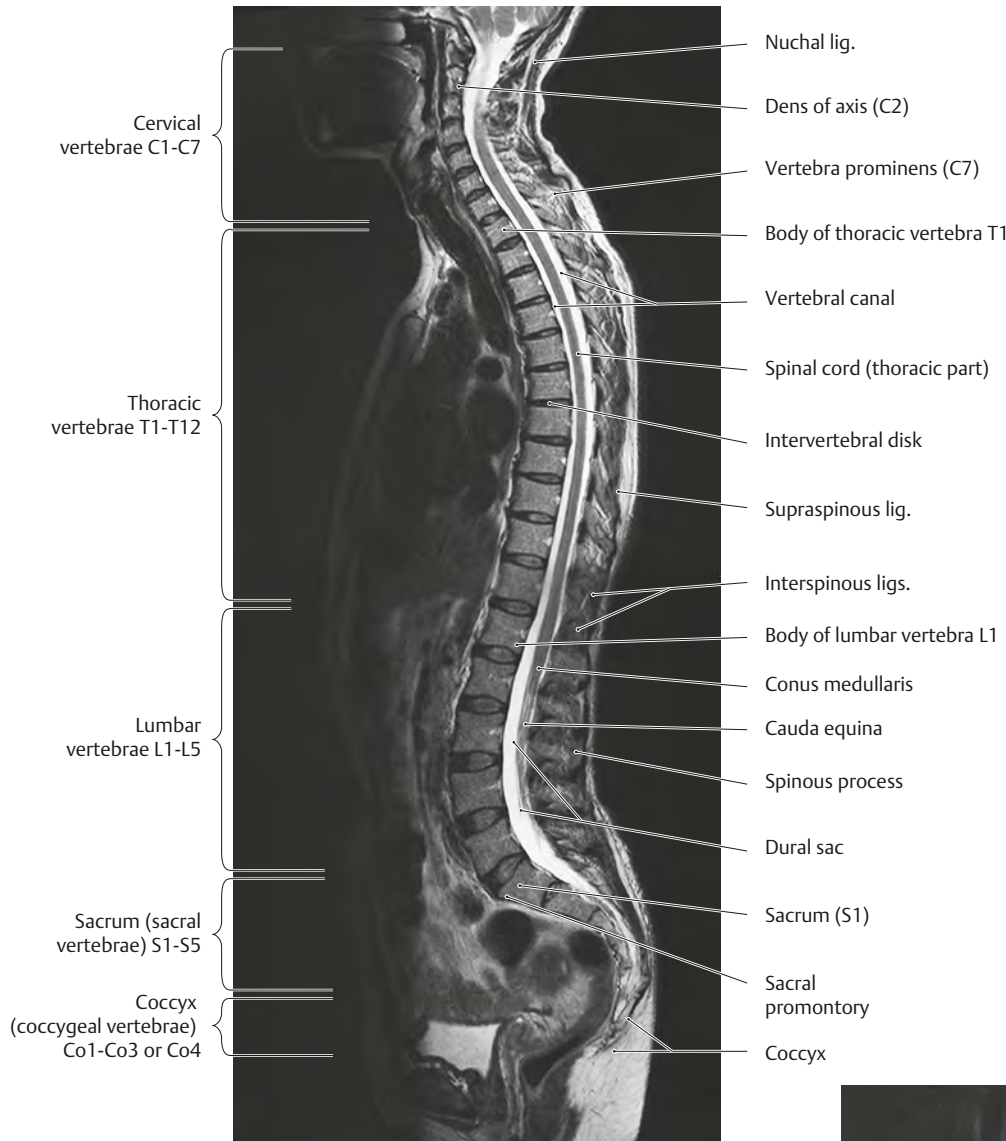


Fig. 5.1 MRI of the spine
Sagittal view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

Fig. 5.2 MRI of the lumbar spine
Parasagittal view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

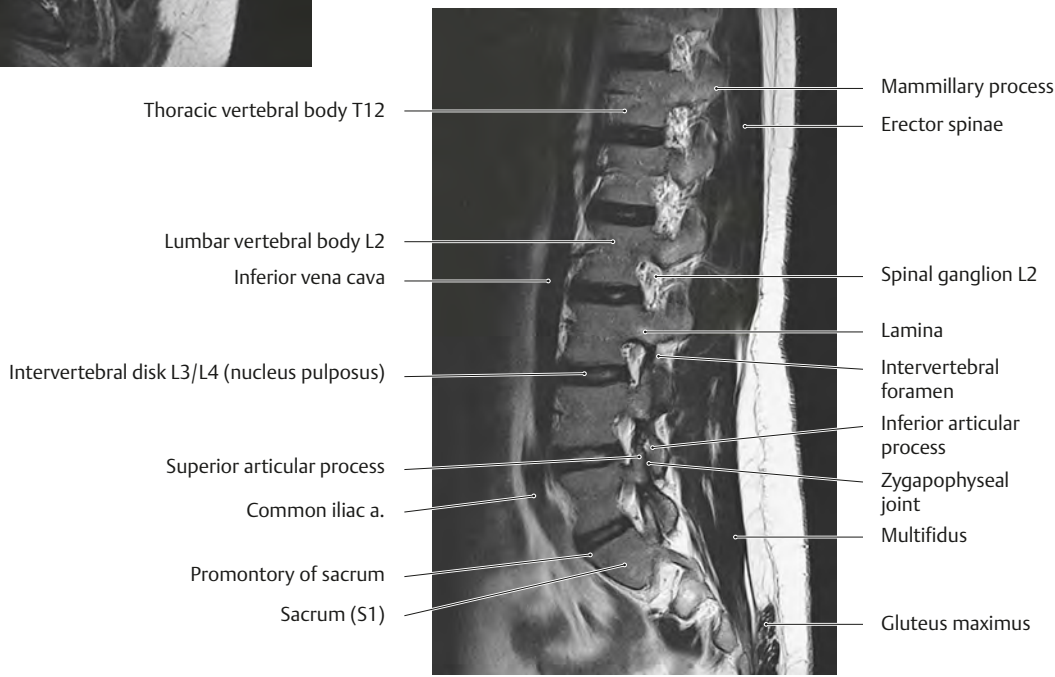
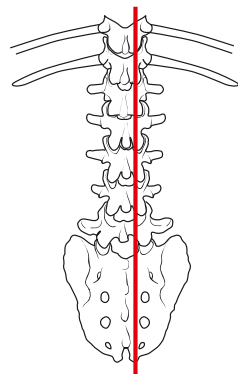


Fig. 5.3 Radiograph of the cervical spine

Lateral view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

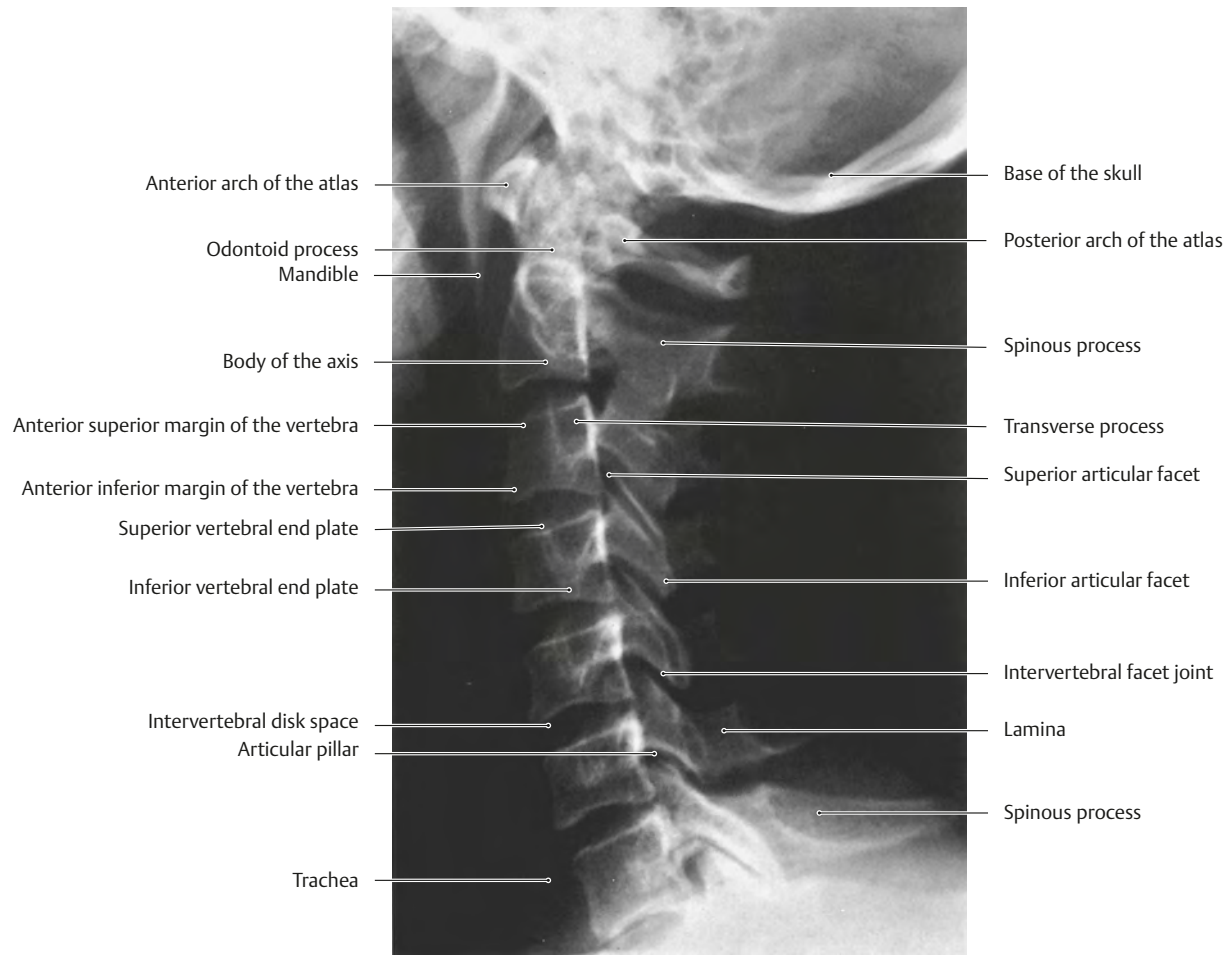
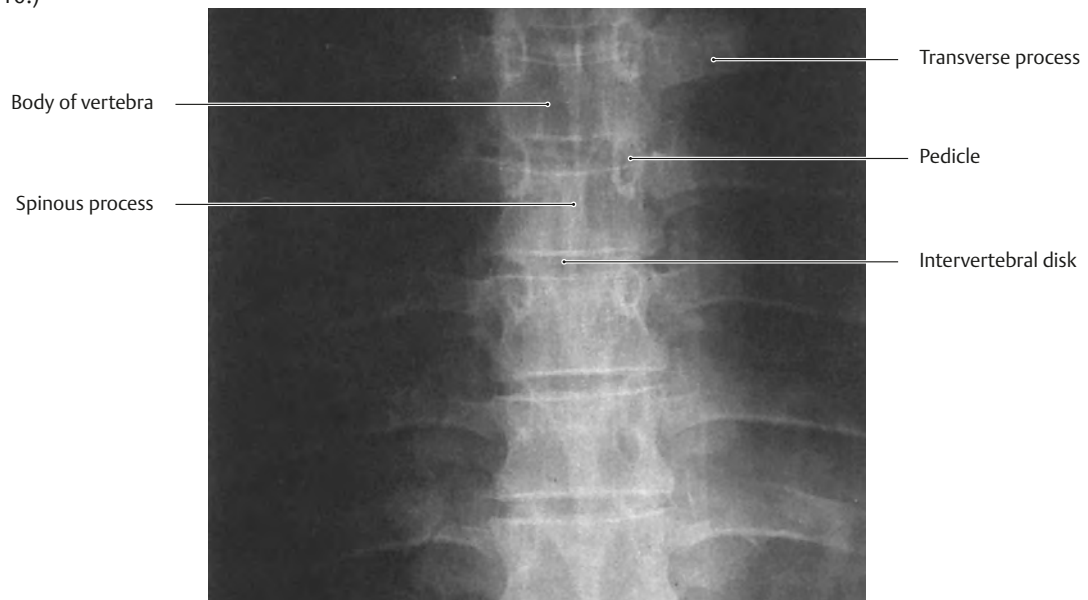


Fig. 5.4 Radiograph of the thoracic spine

Anteroposterior view. Lower thoracic region. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)



Radiographic Anatomy of the Back (II)

Fig. 5.5 Radiograph of the lumbar spine

Lateral view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

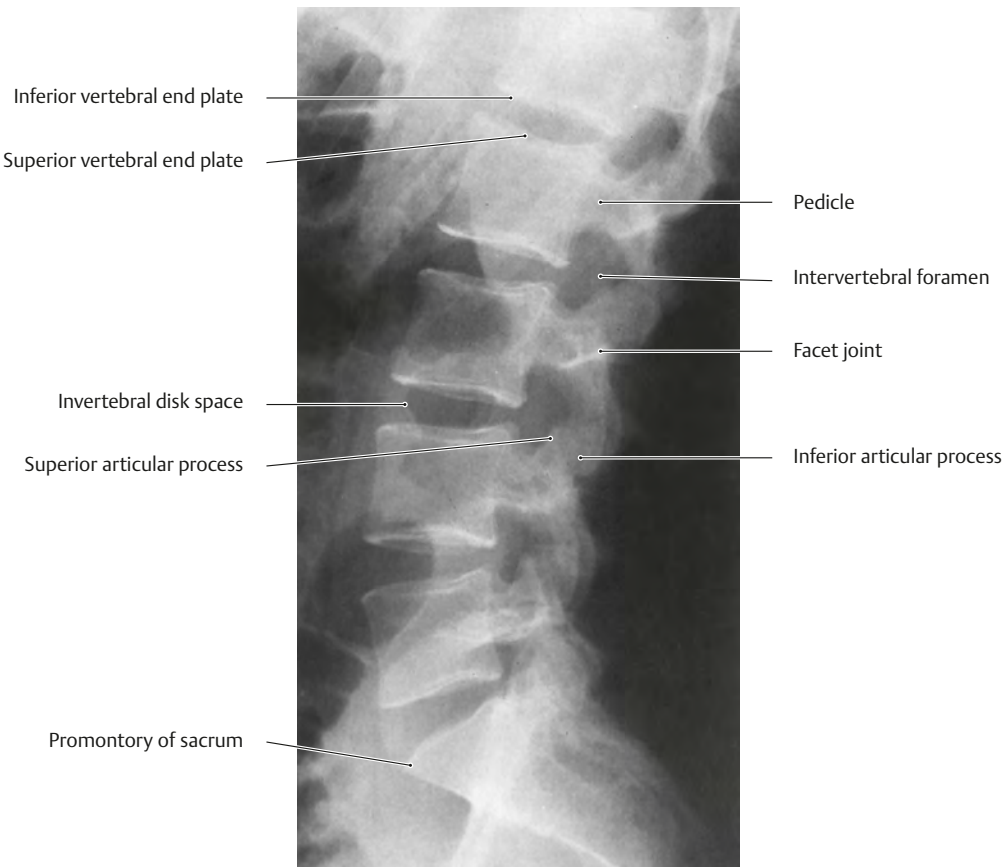


Fig. 5.6 Radiograph of the lumbar spine

Oblique view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

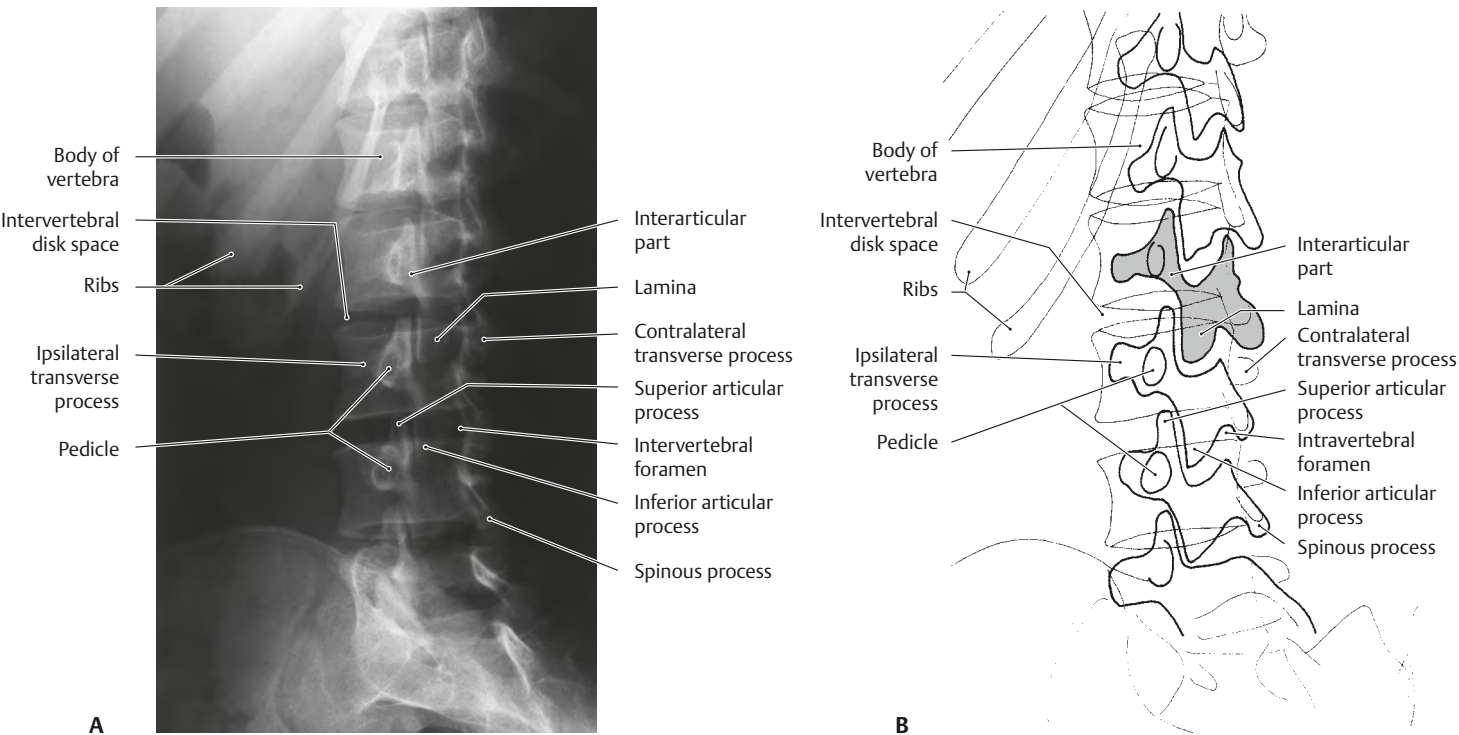
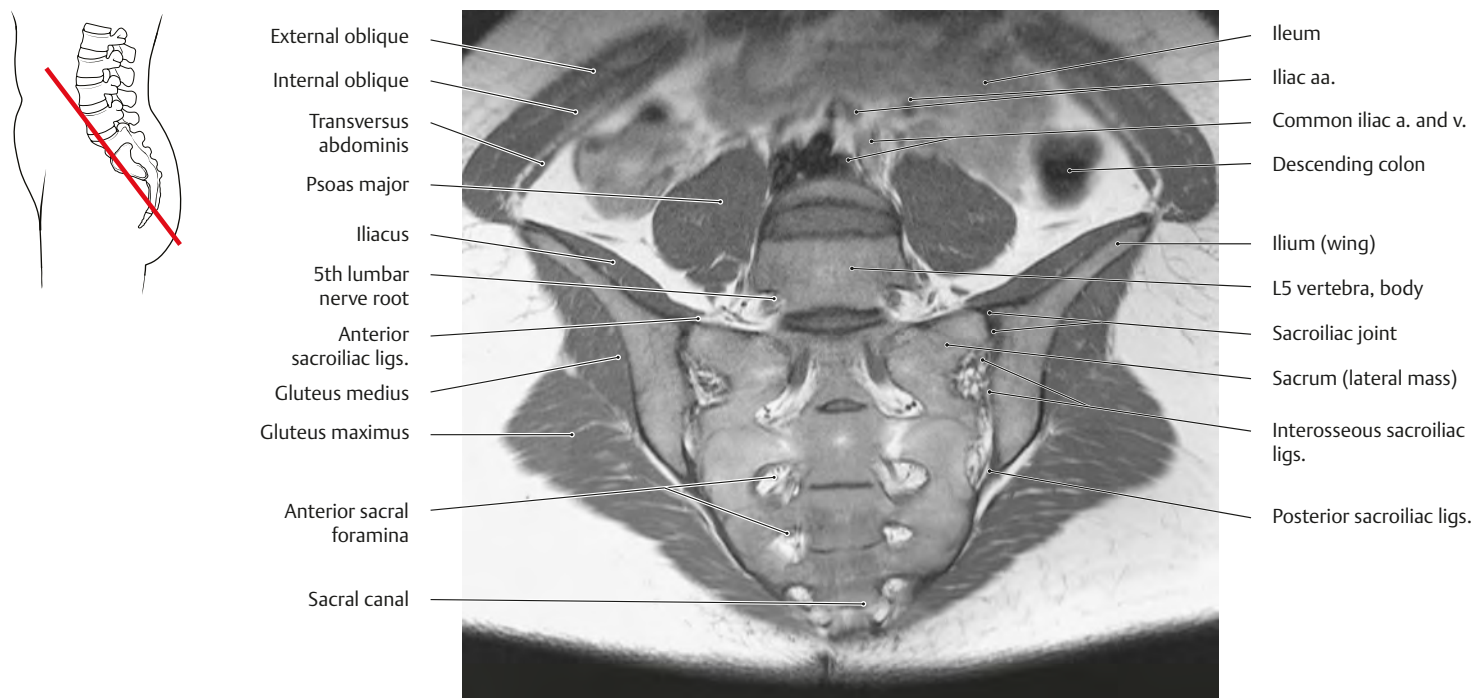
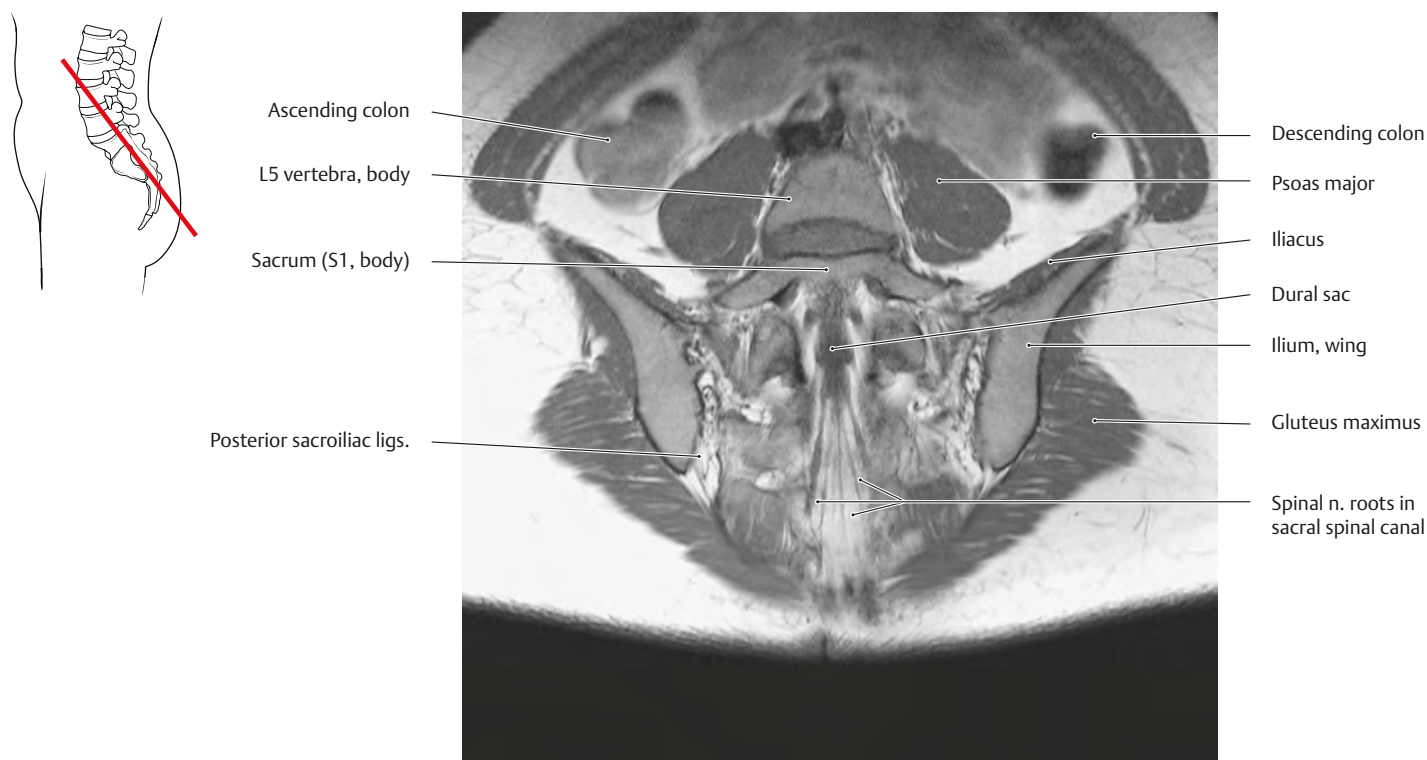


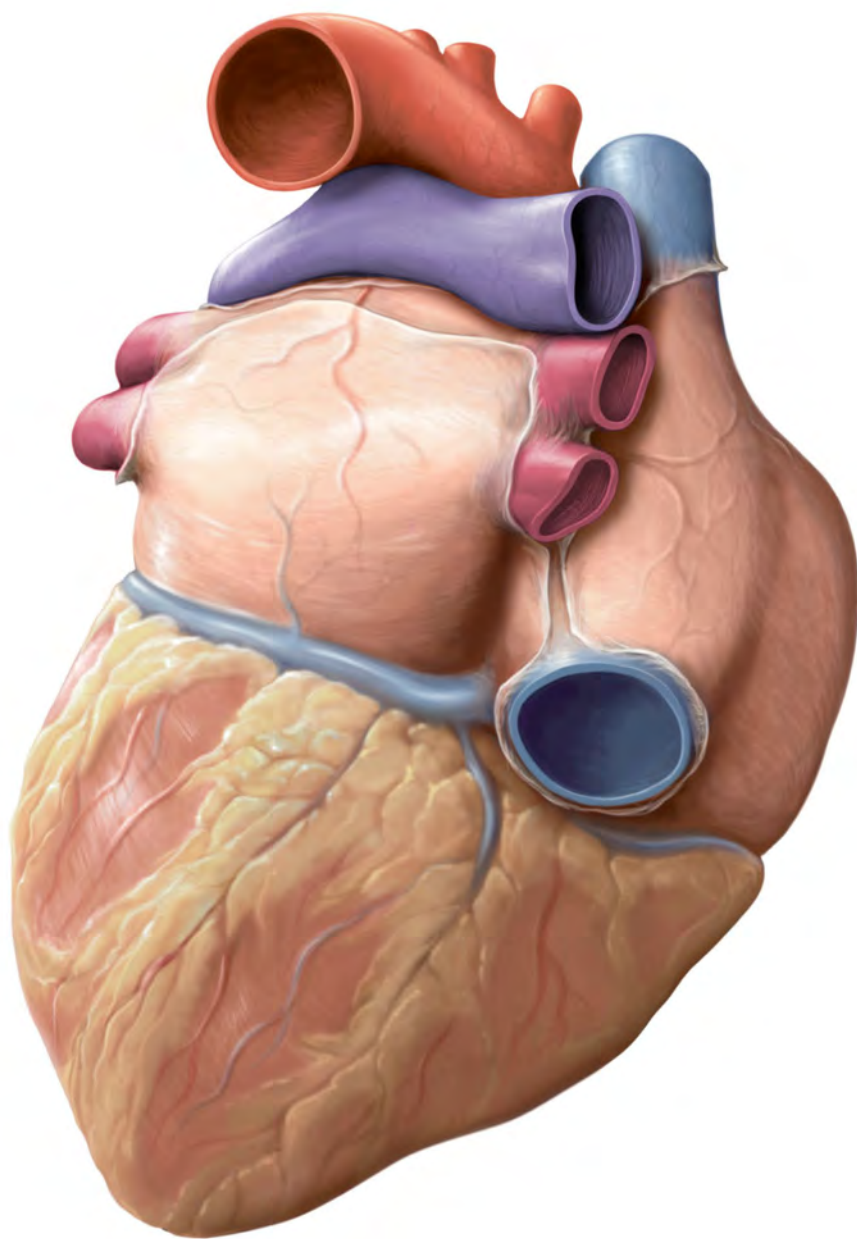
Fig. 5.7 MRI of the sacrum I

Oblique view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

**Fig. 5.8 MRI of the sacrum II**

Oblique view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)





Thorax

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6 Surface Anatomy

Surface Anatomy

Fig. 6.1 Regions of the thorax
Anterior view.

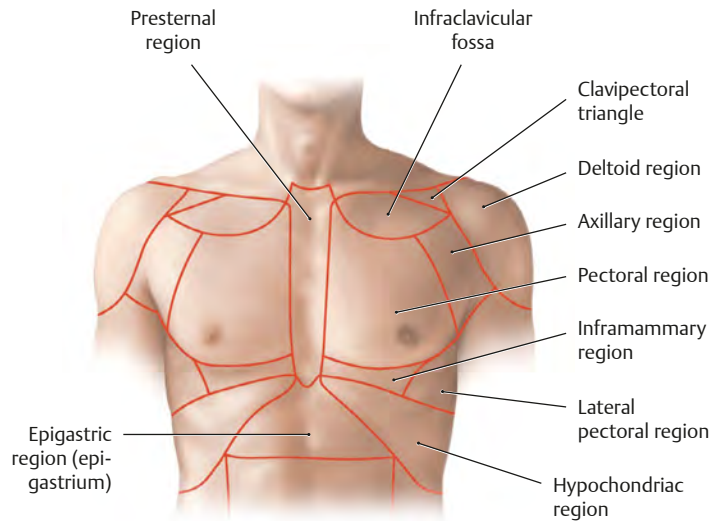
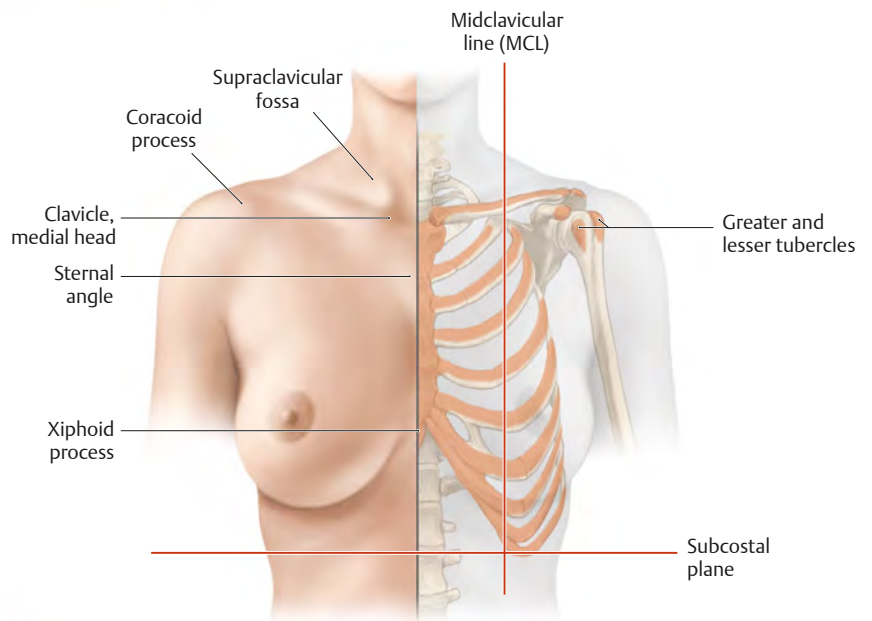
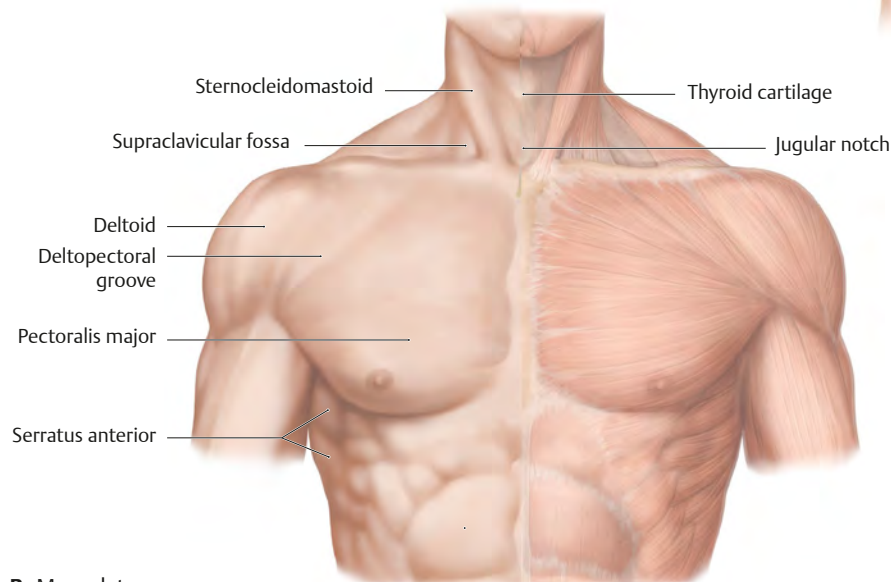


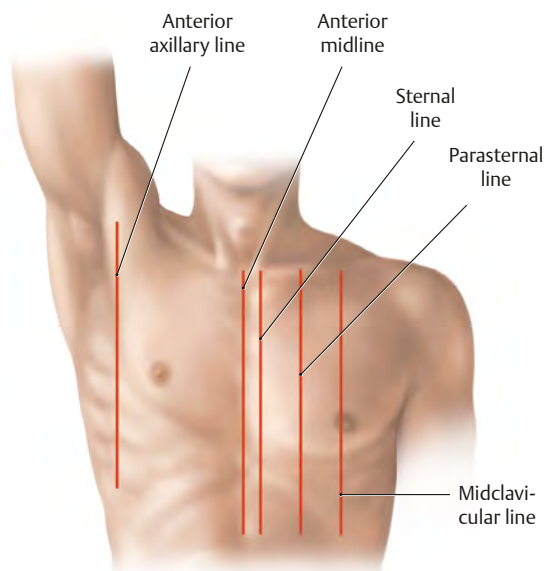
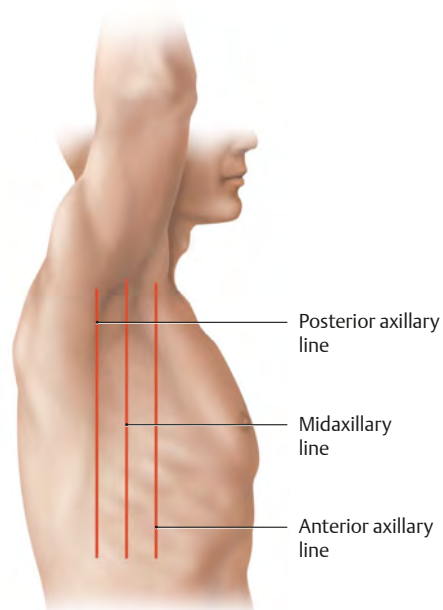
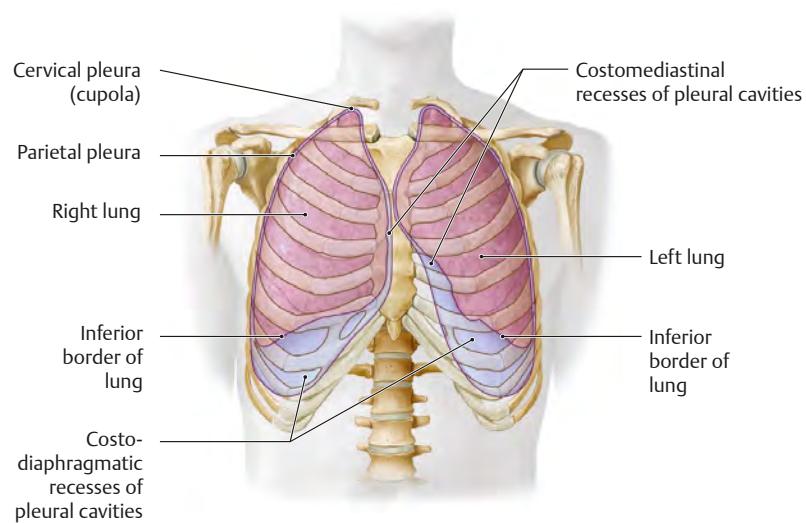
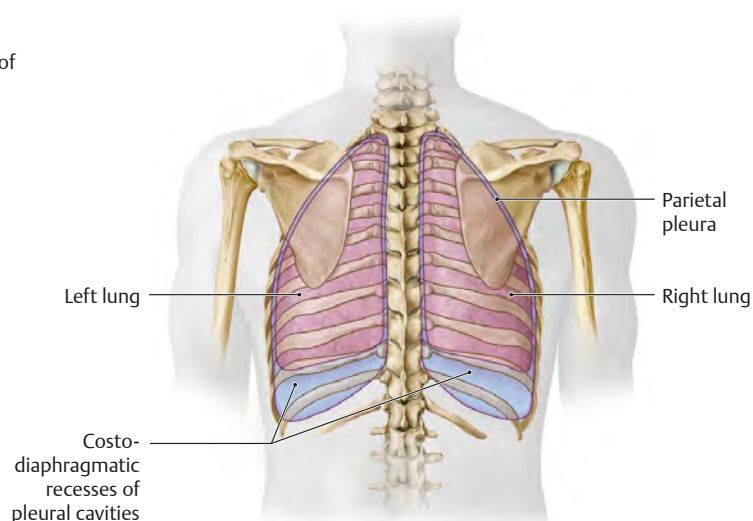
Fig. 6.2 Palpable structures of the thorax
Anterior view.



A Bony prominences.



B Musculature.

Fig. 6.3 Vertical reference lines of the thorax**A** Anterior view.**B** Right lateral view.**Fig. 6.4 Pleural cavities and lungs projected onto the thoracic skeleton****A** Anterior view.**B** Posterior view.

7 Thoracic Wall

Thoracic Skeleton

The thoracic skeleton consists of 12 thoracic vertebrae (p. 10), 12 pairs of ribs with costal cartilages, and the sternum. In addition to participating in respiratory movements, it provides a measure of protection to

vital organs. The female thorax is generally narrower and shorter than the male equivalent.

Fig. 7.1 Thoracic skeleton

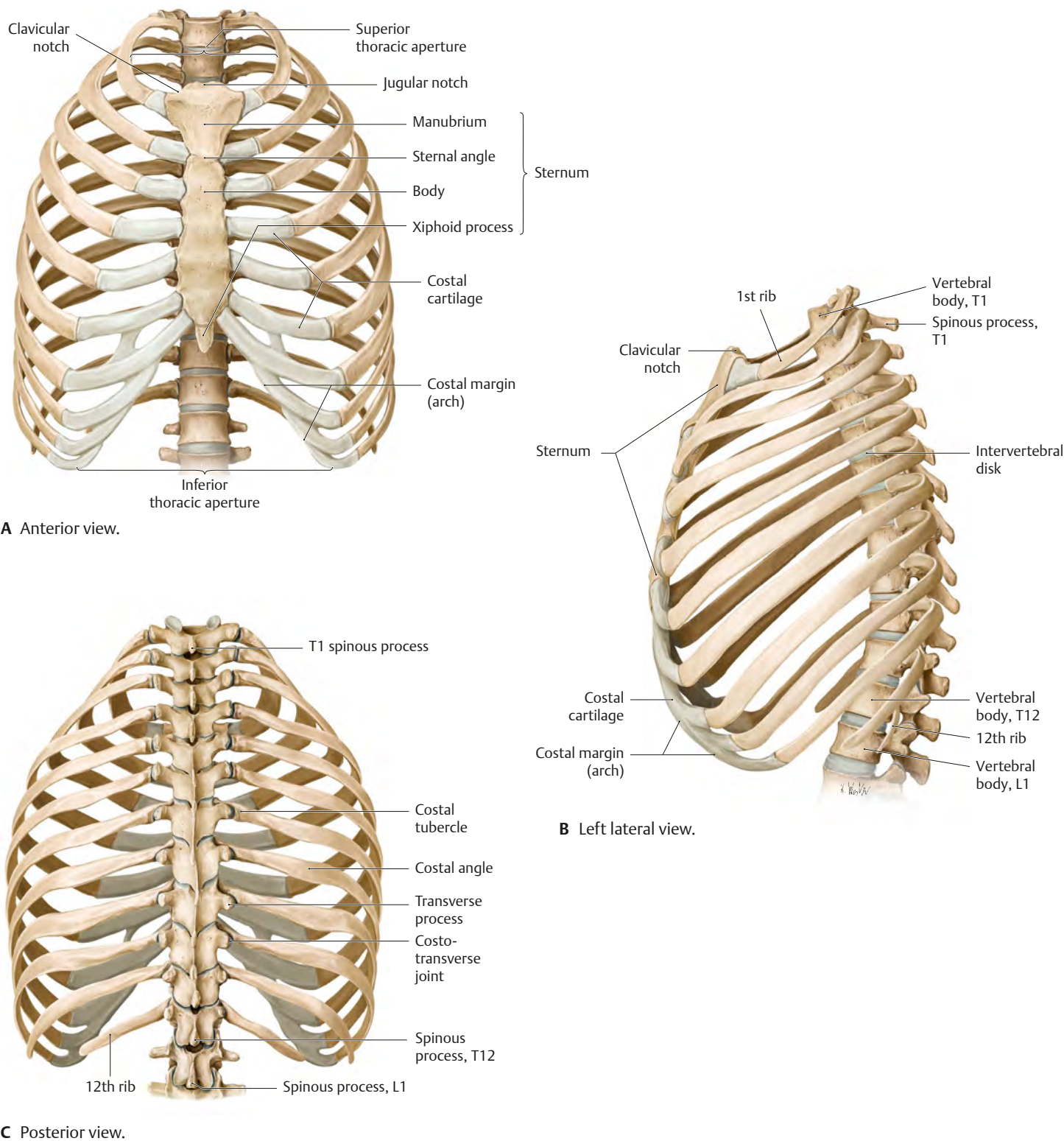


Fig. 7.2 Structure of a thoracic segment
Superior view of 6th rib pair.

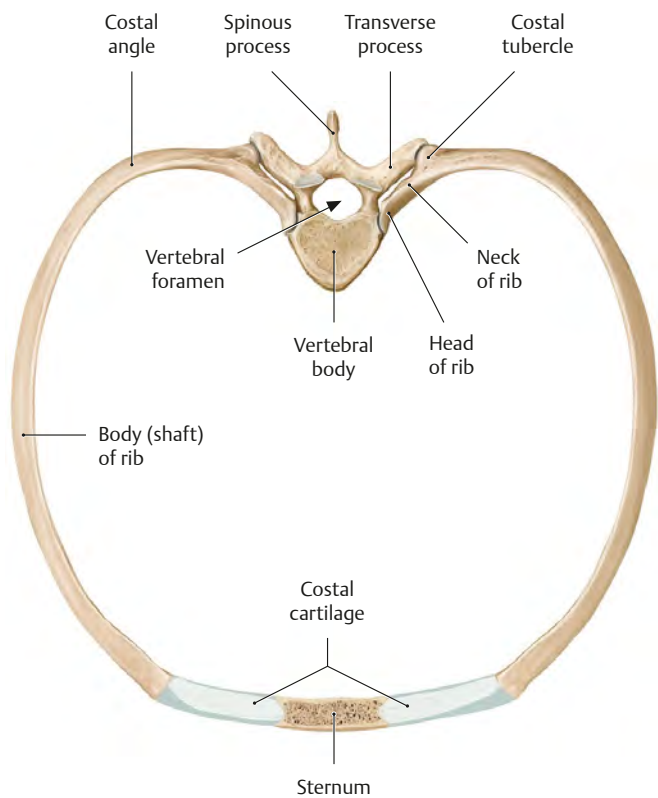
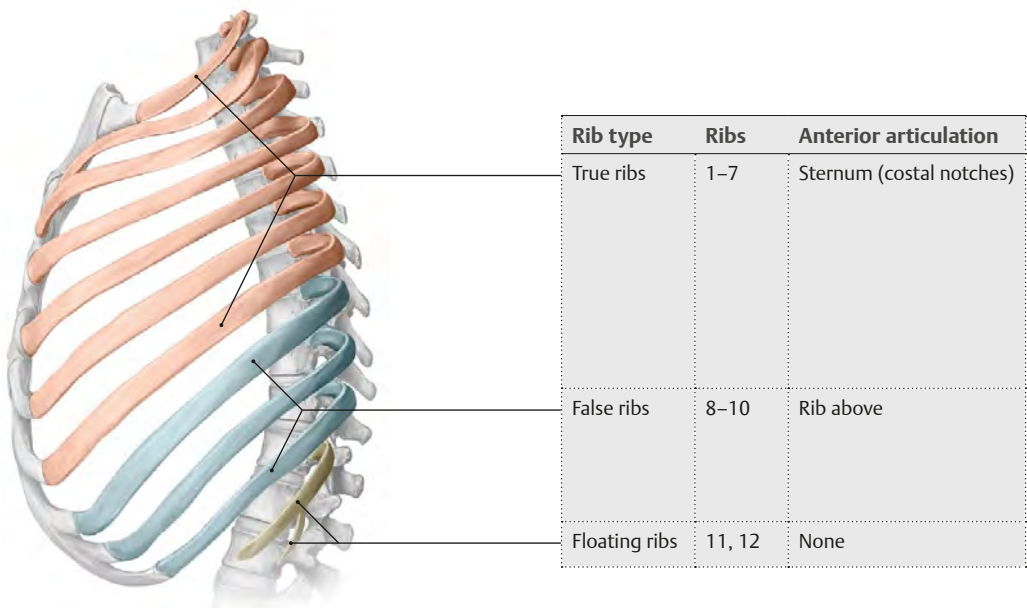


Table 7.1			Elements of a thoracic segment	
Vertebra				
Rib	Bony part (costal bone)		Head	
			Neck	
			Costal tubercle	
			Body (including costal angle)	
	Costal part (costal cartilage)			
Sternum (articulates with costal cartilage of true ribs only; see Fig. 7.3)				

Fig. 7.3 Types of ribs
Left lateral view.

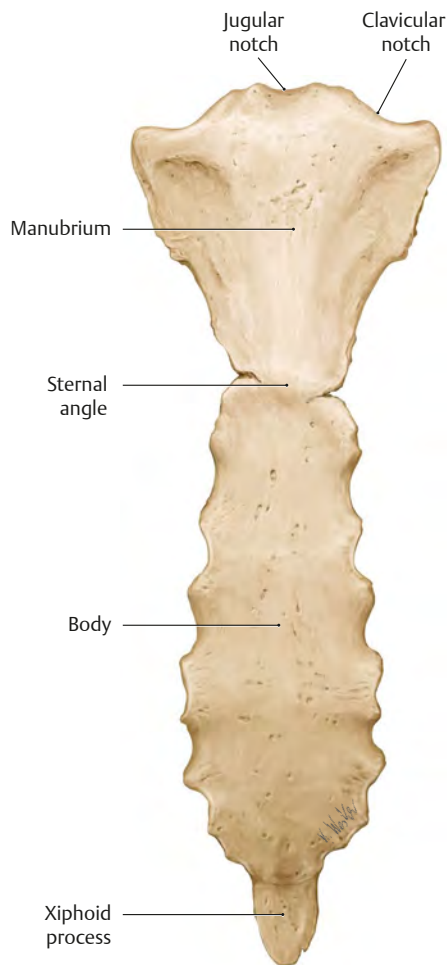


Rib type	Ribs	Anterior articulation
True ribs	1–7	Sternum (costal notches)
False ribs	8–10	Rib above
Floating ribs	11, 12	None

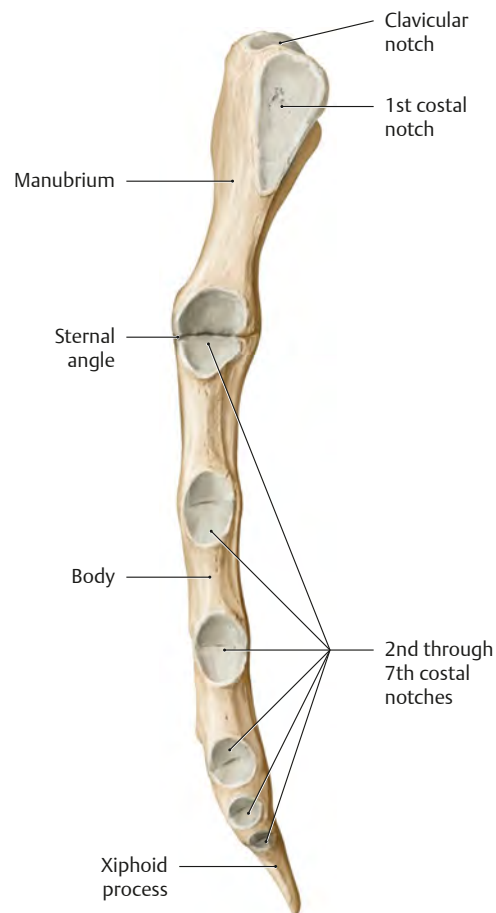
Sternum & Ribs

Fig. 7.4 Sternum

The sternum is a dagger-like bone consisting of the manubrium (the handle), body (blade), and xiphoid process (tip of blade). The junction of the manubrium and body (the sternal angle) is typically elevated and marks the articulation of the second rib. The sternal angle (projected posteriorly to intersect with T4/5) is an important landmark for internal structures.



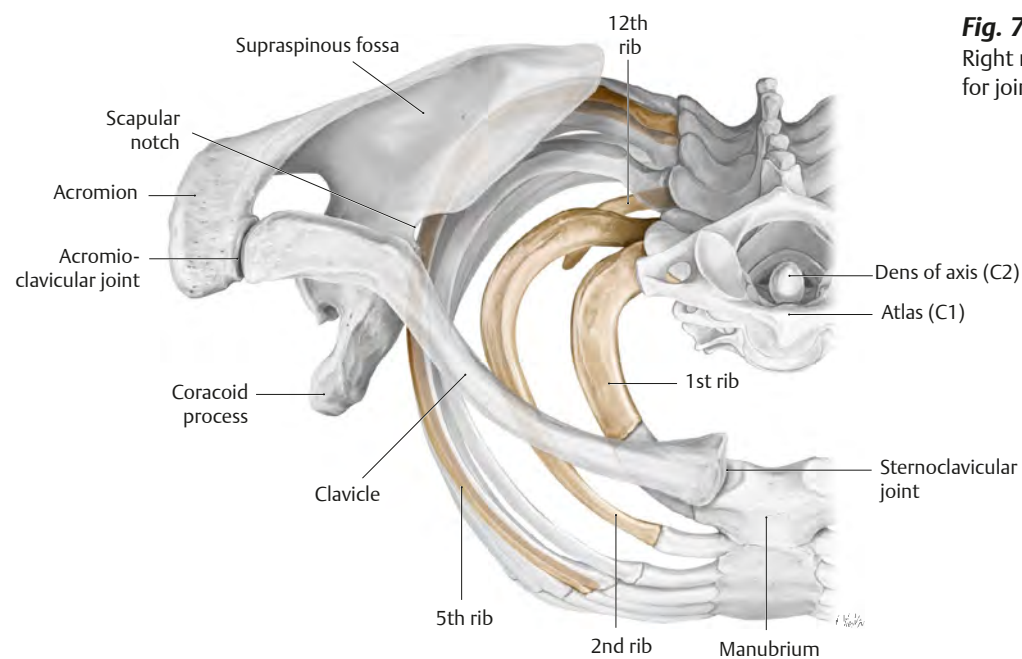
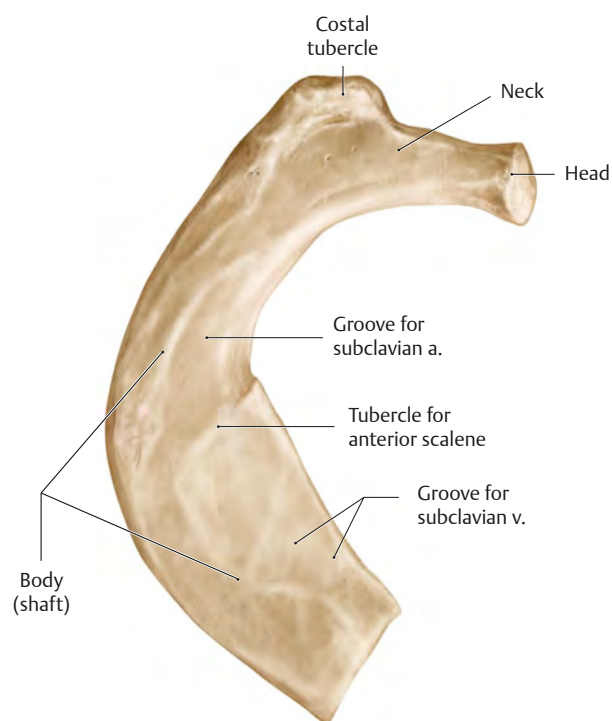
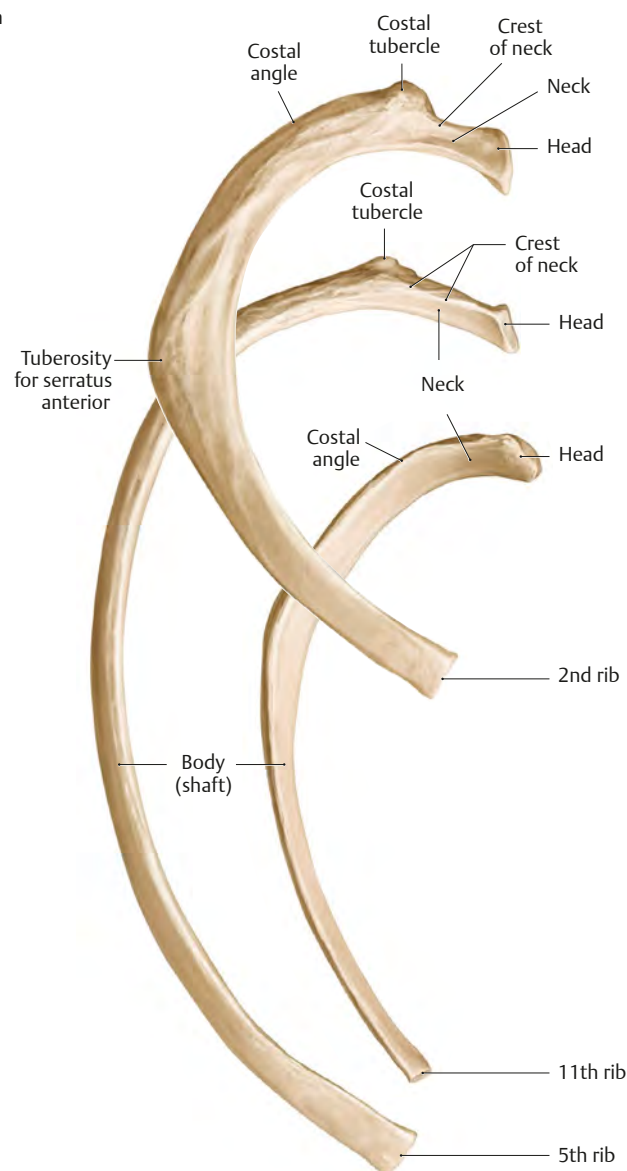
A Anterior view.



B Left lateral view. The costal notches are sites of articulation with the costal cartilage of the true ribs (see **Fig. 7.3**).

Fig. 7.5 Ribs

Right ribs, superior view. See pp. 298–299 for joints of the shoulder.

**A** Variations in rib size and shape.**B** 1st rib. Most ribs have a costal groove along the inferior border (See Fig. 7.24), which protects the intercostal vessels and nerves.**C** Right ribs, superior view.

Joints of the Thoracic Cage

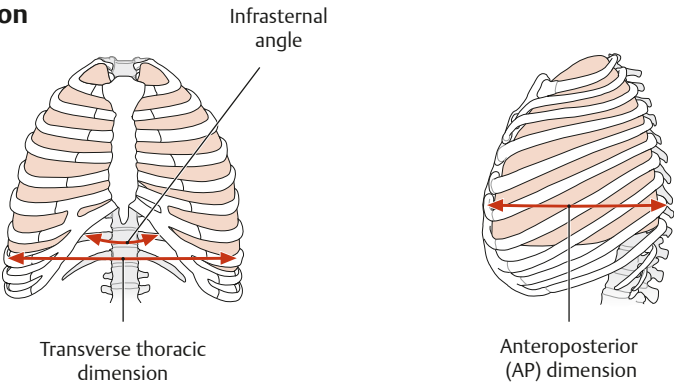
The diaphragm is the chief muscle for quiet respiration (see p. 64). The muscles of the thoracic wall (see p. 62) contribute to deep (forced) inspiration.

Fig. 7.6 Rib cage movement

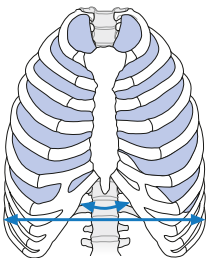
Full inspiration (red); full expiration (blue). In deep inspiration, there is an increase in transverse and anteroposterior (AP) dimensions, as well as the infrasternal angle. Note the red lines (inspiration dimensions)

on the diagrams are longer than the blue ones (expiration dimensions) below. The downward movement of the diaphragm further increases the volume of the thoracic cavity.

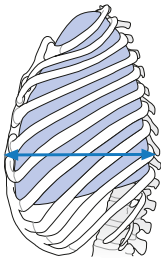
Inspiration



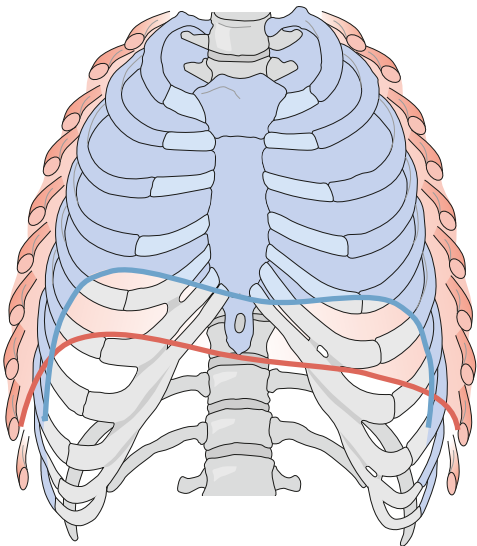
Expiration



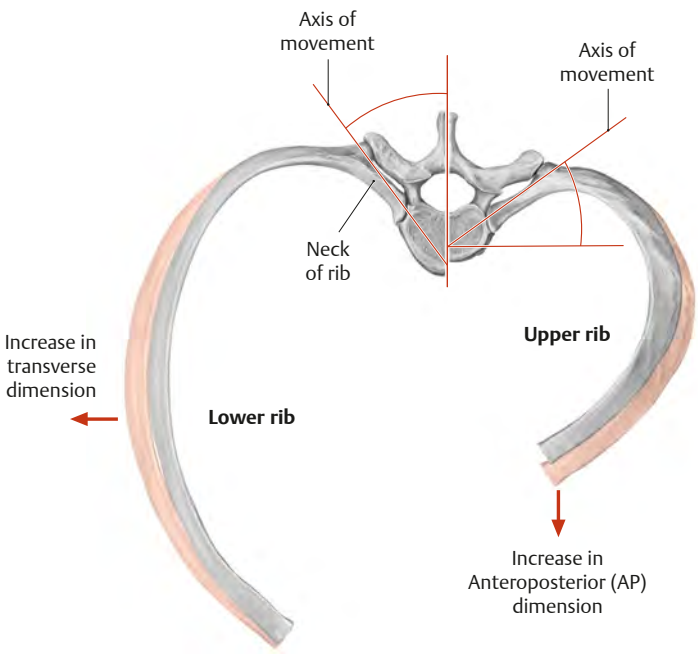
A Anterior view.



B Left lateral view.



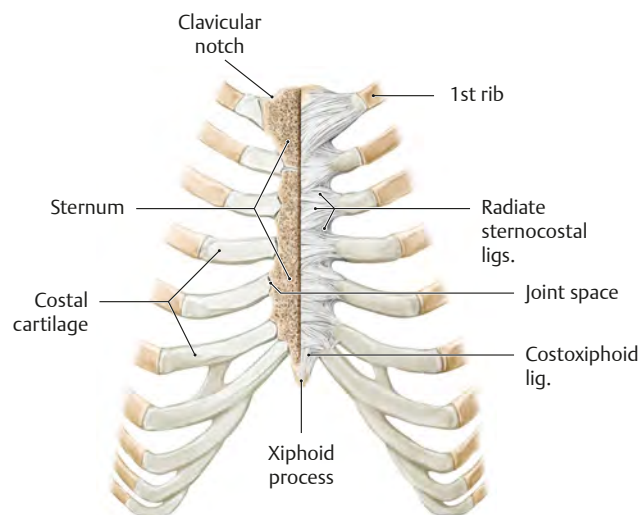
C Position of diaphragm during respiration. Blue line = expiration, red line = inspiration.



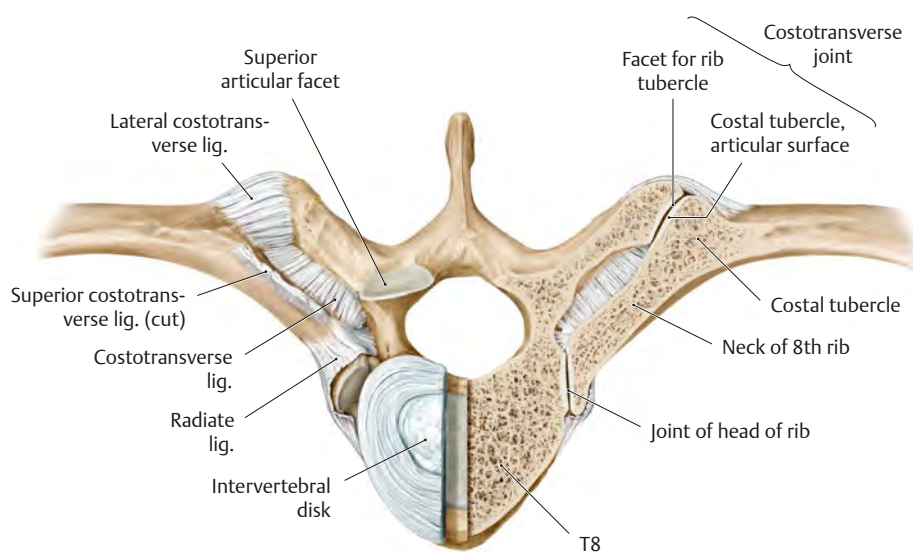
D Axes of rib movement, superior view.

Fig. 7.7 Sternocostal joints

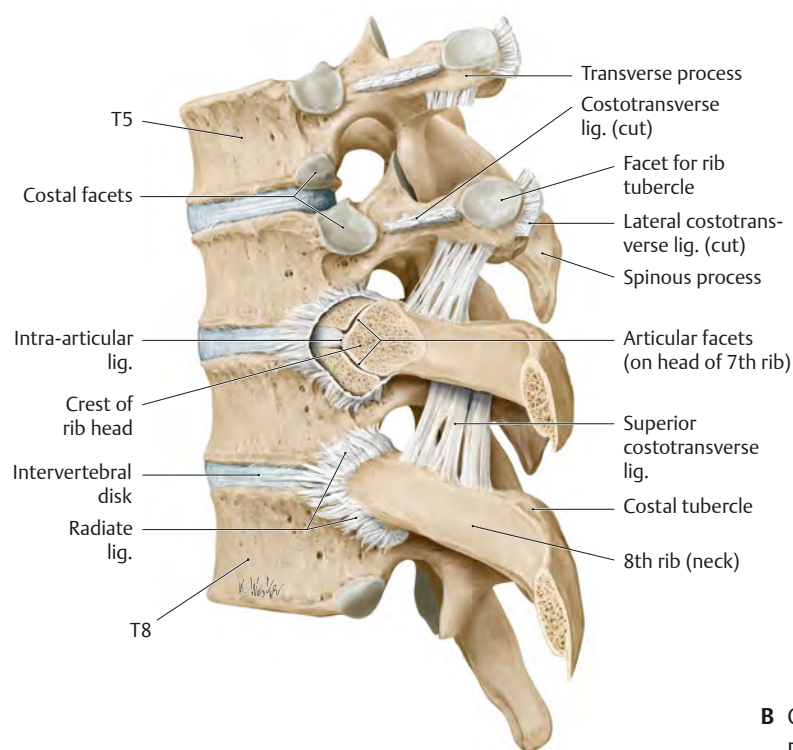
Anterior view with right half of sternum sectioned frontally. True joints are generally found only at ribs 2 to 5; ribs 1, 6, and 7 attach to the sternum by synchondroses.

**Fig. 7.8 Costovertebral joints**

Two synovial joints make up the costovertebral articulation of each rib. The costal tubercle of each rib articulates with the costal facet of its accompanying vertebra (**A**). The head of most ribs articulates with the vertebra of its own number and the vertebra immediately superior. Ribs 1, 11, and 12 typically articulate only with their own vertebrae.



A Costotransverse joint. Superior view with joints of the left rib transversely sectioned.



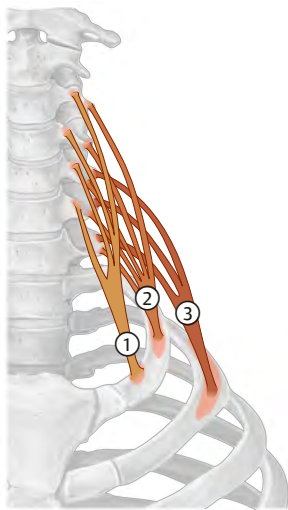
B Costovertebral joints. Left lateral view with the joint head of the 7th rib viewed in sagittal section..

Thoracic Wall Muscle Facts

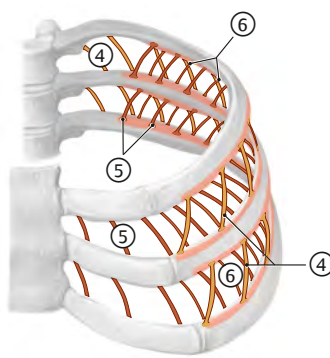
The muscles of the thoracic wall are primarily responsible for ribcage movement during respiration, although other muscles aid in *deep* inspiration: the pectoralis major and serratus anterior are discussed with

the shoulder (see pp. 318–319), and the serratus posterior is discussed with the back (see p. 32).

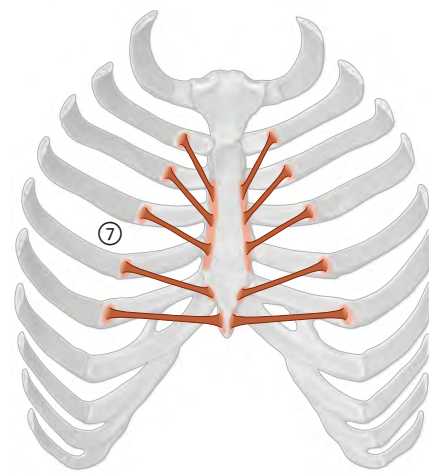
Fig. 7.9 Muscles of the thoracic wall



A Scalene muscles, anterior view.



B Intercostal muscles, anterior view.



C Transversus thoracis, posterior view.

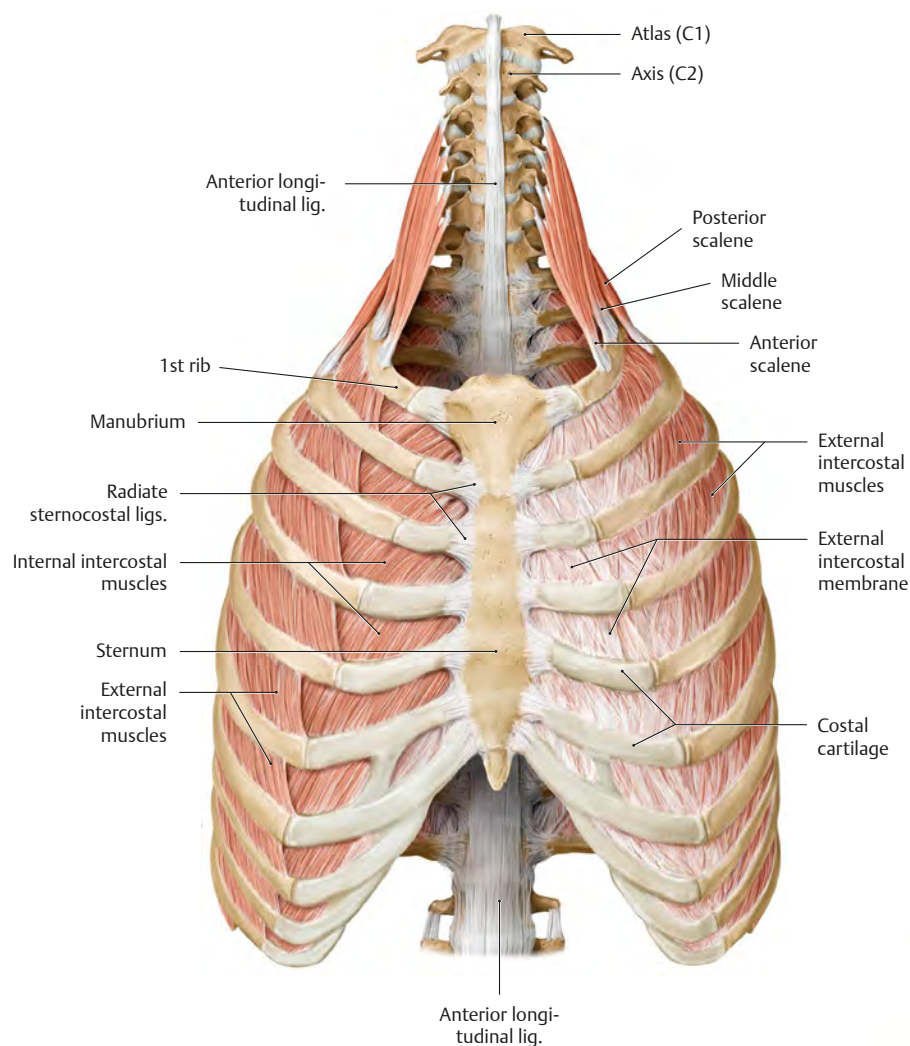
Table 7.2

Muscles of the thoracic wall

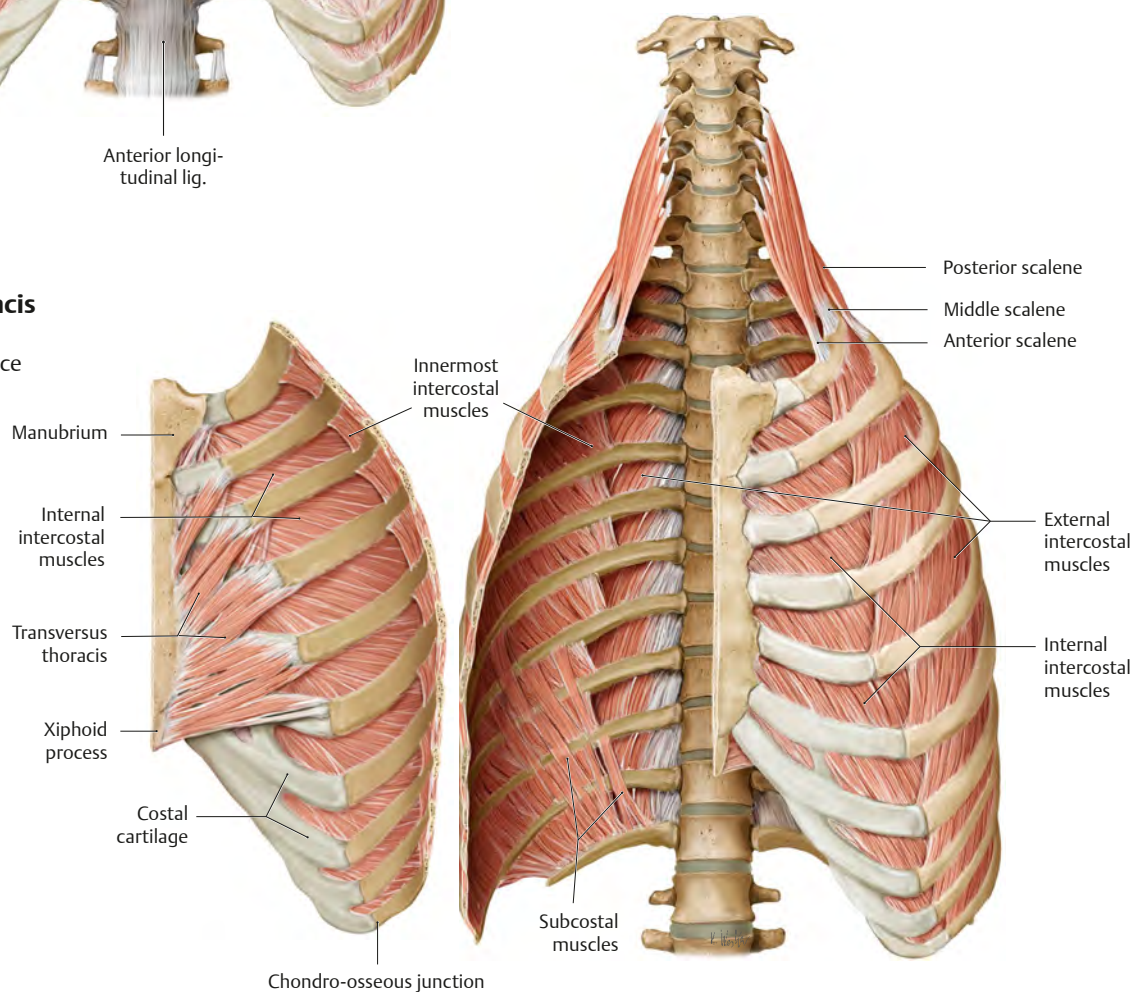
Muscle		Origin	Insertion	Innervation	Action
Scalene mm.	① Anterior scalene m.	C3–C6 (transverse processes, anterior tubercles)	1st rib (anterior scalene tubercle)	Anterior rami of C4–C6 spinal nn.	<i>With ribs mobile:</i> Elevates upper ribs (inspiration) <i>With ribs fixed:</i> Flexes cervical spine to same side (unilateral); flexes neck (bilateral)
	② Middle scalene m.	C1–C2 (transverse processes) C3–C7 (transverse processes, posterior tubercles)	1st rib (posterior to groove for subclavian a.)	Anterior rami of C3–C8 spinal nn.	
	③ Posterior scalene m.	C5–C7 (transverse processes, posterior tubercles)	2nd rib (outer surface)	Anterior rami of C6–C8 spinal nn.	
Intercostal mm.	④ External intercostal mm.	Lower margin of rib to upper margin of next lower rib (courses obliquely forward and downward from costal tubercle to chondro-osseous junction)		1st to 11th intercostal nn.	Elevates ribs (inspiration); supports intercostal spaces; stabilizes chest wall
	⑤ Internal intercostal mm.	Lower margin of rib to upper margin of next lower rib (courses obliquely forward and upward from costal angle to sternum)			Depresses ribs (expiration); supports intercostal spaces, stabilizes chest wall
	⑥ Innermost intercostal mm.				
Subcostal mm.		Lower margin of lower ribs to inner surface of ribs two to three ribs below		Adjacent intercostal nn.	Depresses ribs (expiration)
⑦ Transversus thoracis m.		Sternum and xiphoid process (inner surface)	2nd to 6th ribs (costal cartilage, inner surface)	2nd to 6th intercostal nn.	Weakly depresses ribs (expiration)

Fig. 7.10 Muscles of the thoracic wall

Anterior view. The external intercostal muscles are replaced anteriorly by the external intercostal membrane. The internal intercostal muscles are replaced posteriorly by the internal intercostal membrane.

**Fig. 7.11 Transversus thoracis**

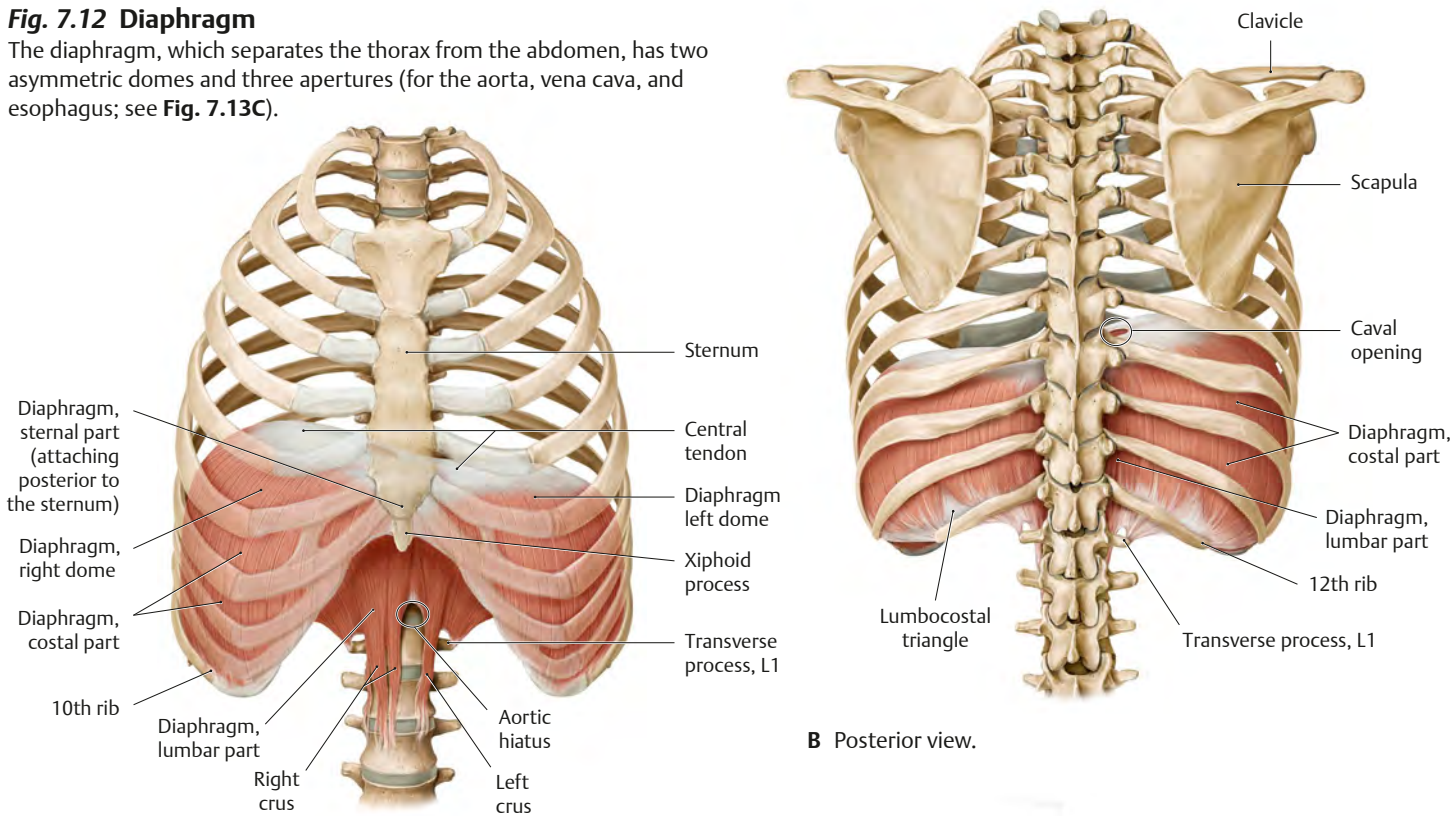
Anterior view with thoracic cage opened to expose posterior surface of anterior wall. The external and internal intercostal membranes have been removed.



Diaphragm

Fig. 7.12 Diaphragm

The diaphragm, which separates the thorax from the abdomen, has two asymmetric domes and three apertures (for the aorta, vena cava, and esophagus; see Fig. 7.13C).



A Anterior view.

C Coronal section with diaphragm in intermediate position.

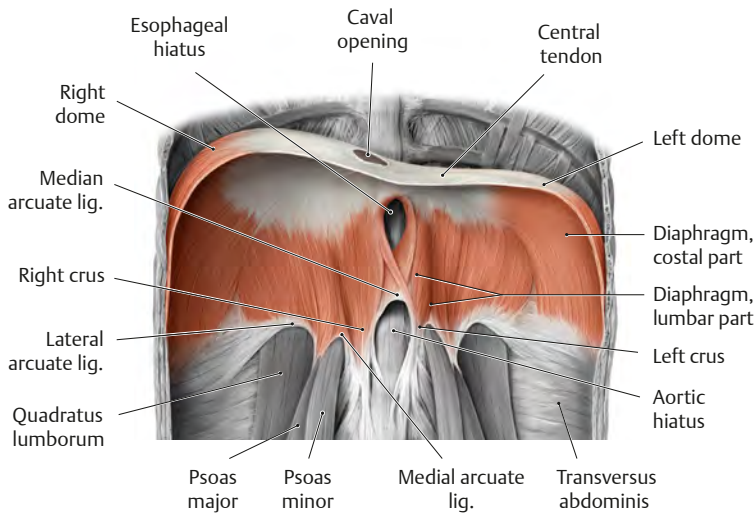
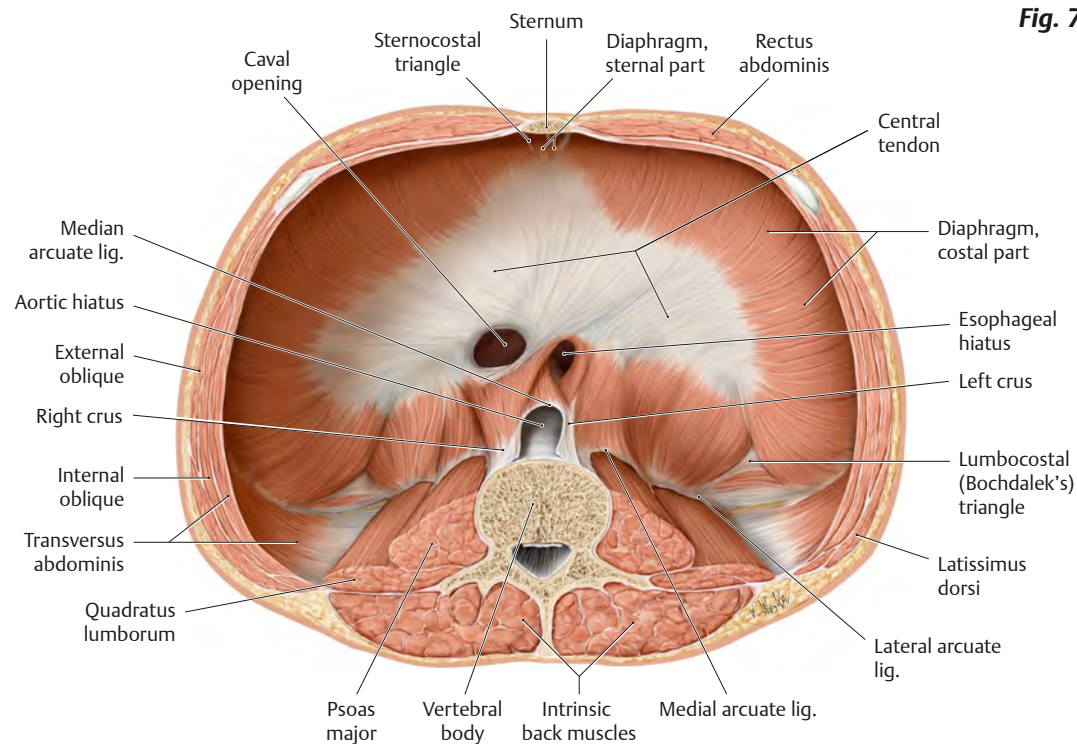
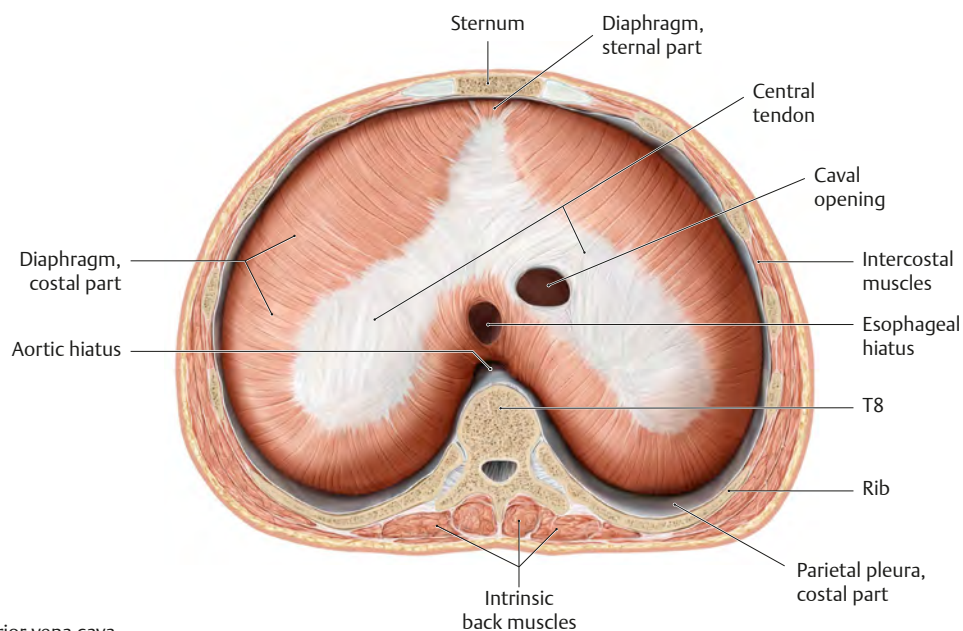


Table 7.3 Diaphragm					
Muscle		Origin	Insertion	Innervation	Action
Diaphragm	Costal part	7th to 12th ribs (inner surface; lower margin of costal arch)	Central tendon	Phrenic n. (C3–C5, cervical plexus)	Principal muscle of respiration (diaphragmatic and thoracic breathing); aids in compressing abdominal viscera (abdominal press)
	Lumbar part	Medial part: L1–L3 vertebral bodies, intervertebral disks, and anterior longitudinal lig. as right and left crura Lateral parts: lateral and medial arcuate lig.			
	Sternal part	Xiphoid process (posterior surface)			

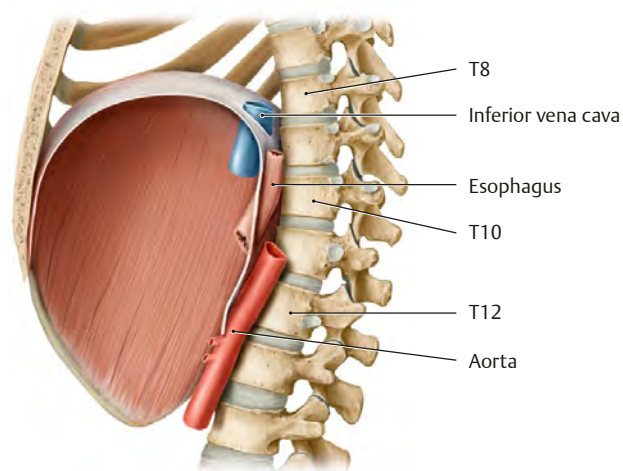
Fig. 7.13 Diaphragm in situ



A Inferior view.



B Superior view.



C Diaphragmatic apertures, left lateral view.

Neurovasculature of the Diaphragm

Fig. 7.14 Neurovasculature of the diaphragm
Anterior view of opened thoracic cage.

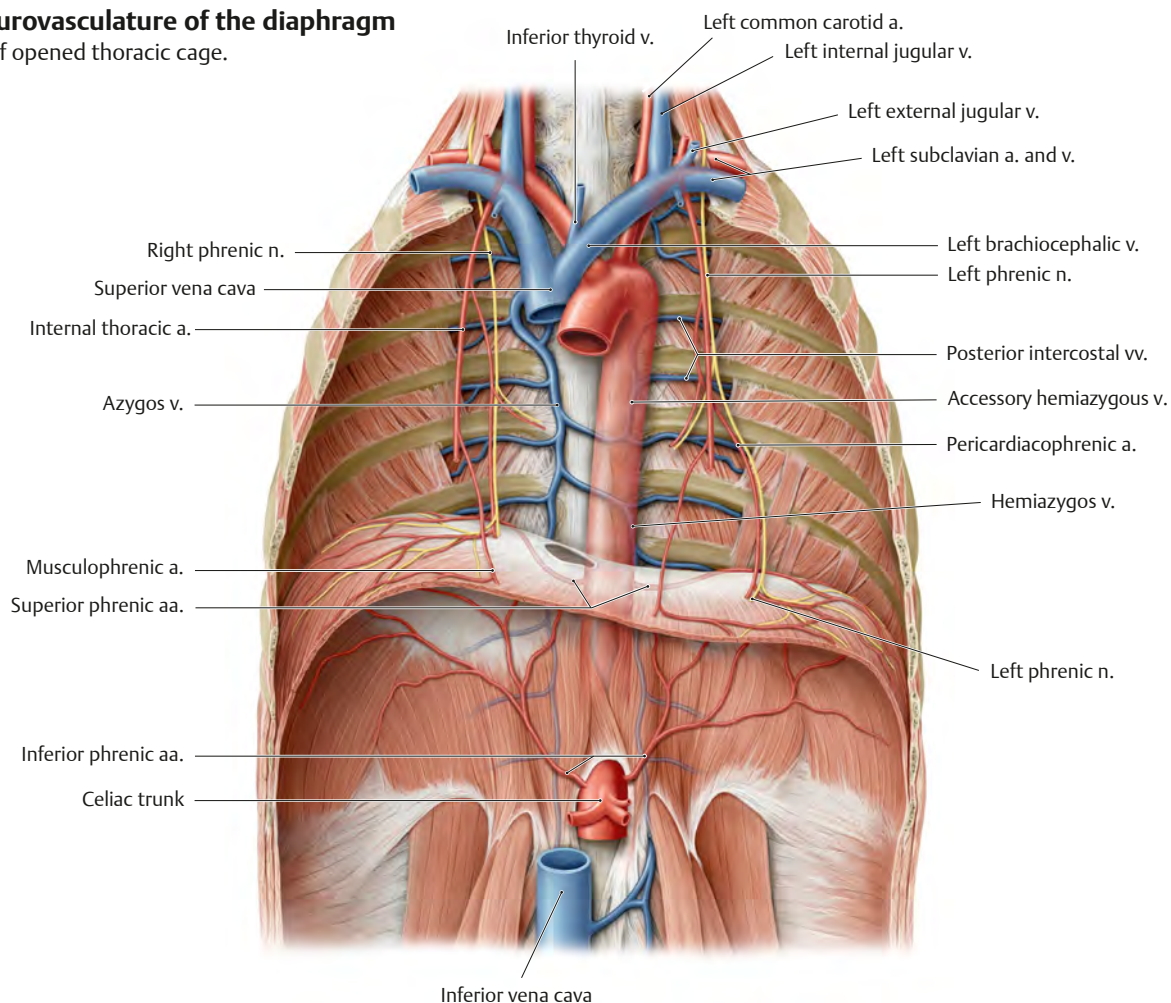


Fig. 7.15 Innervation of the diaphragm

Anterior view. The phrenic nerves lie on the lateral surfaces of the fibrous pericardium together with the pericardiophrenic arteries and veins. *Note:* The phrenic nerves also innervate the pericardium.

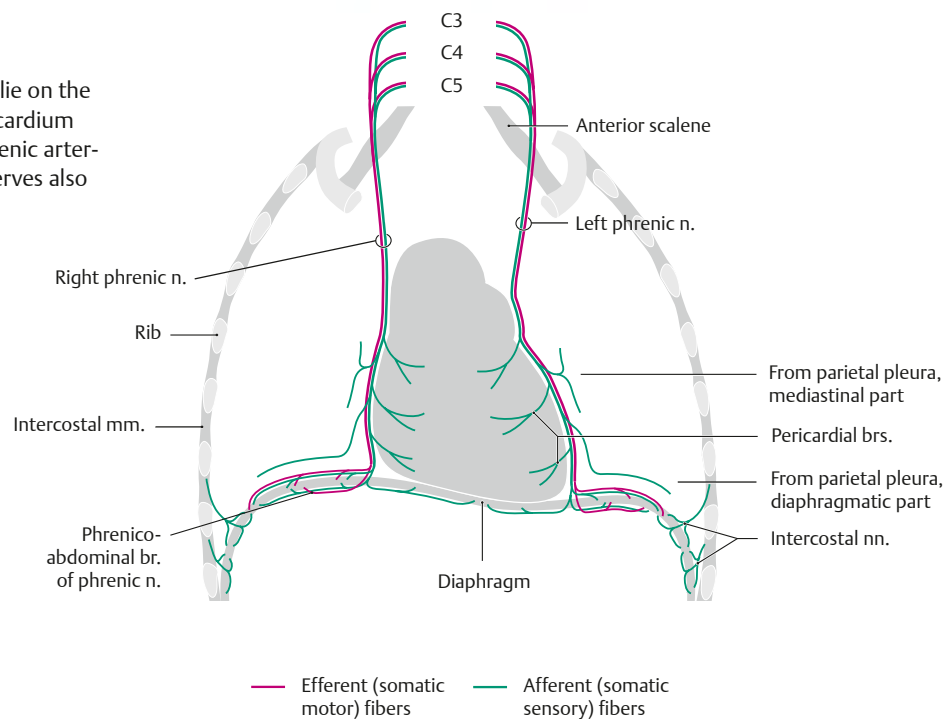
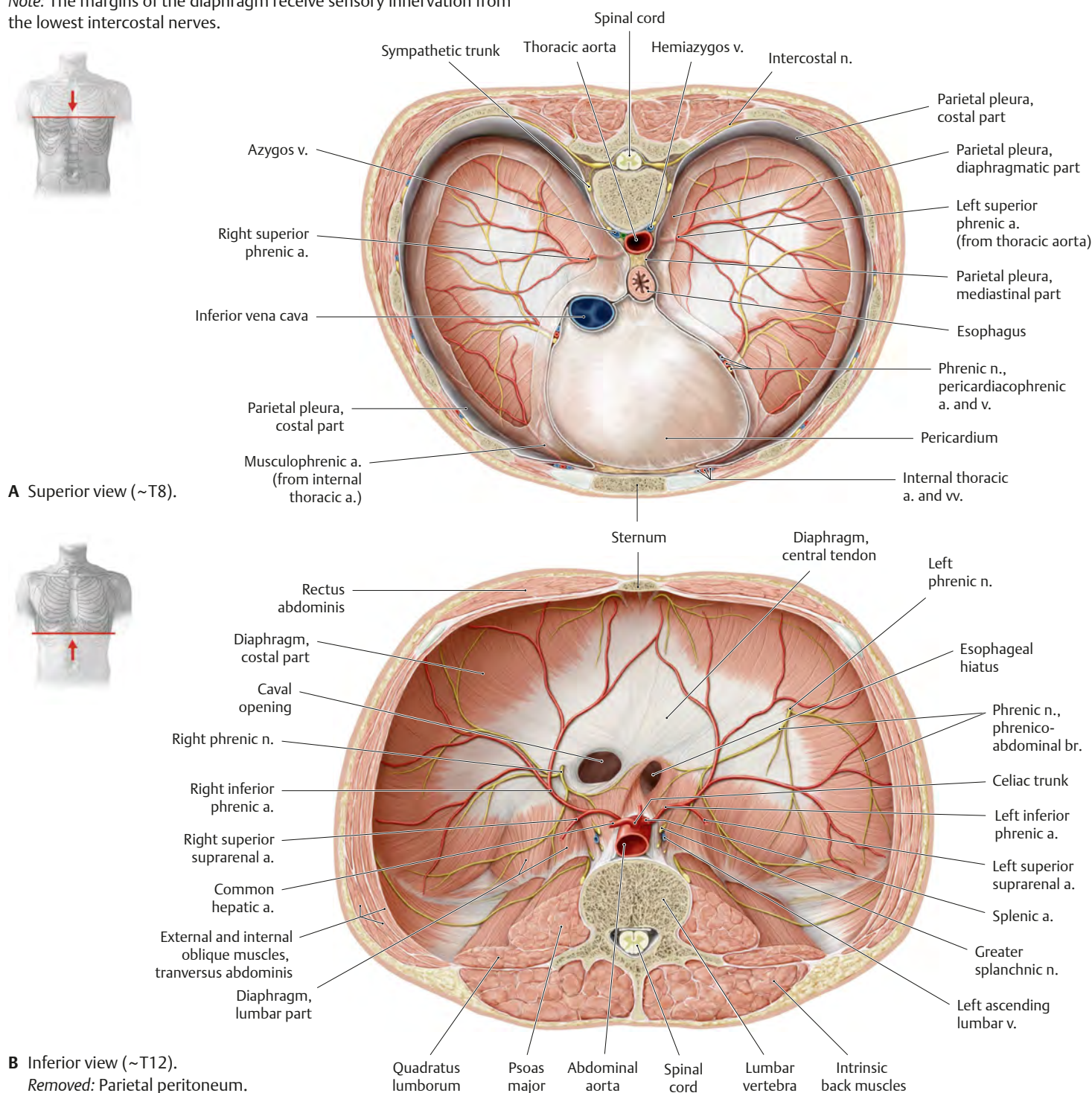


Table 7.4 Blood vessels of the diaphragm

Artery	Origin	Vein	Drainage
Inferior phrenic aa. (chief blood supply)	Abdominal aorta; occasionally from celiac trunk	Inferior phrenic vv.	Inferior vena cava
Superior phrenic aa.	Thoracic aorta	Superior phrenic vv.	Azygos v. (right side), hemiazygos v. (left side)
Pericardiophrenic aa.	Internal thoracic aa.	Pericardiophrenic vv.	Internal thoracic vv. or brachiocephalic vv.
Musculophrenic aa.		Musculophrenic vv.	Internal thoracic vv.

Fig. 7.16 Arteries and nerves of the diaphragm

Note: The margins of the diaphragm receive sensory innervation from the lowest intercostal nerves.



Arteries & Veins of the Thoracic Wall

The posterior intercostal arteries anastomose with the anterior intercostal arteries to supply the structures of the thoracic wall. The posterior intercostal arteries branch from the thoracic aorta,

with the exception of the 1st and 2nd, which arise from the superior intercostal artery (a branch of the costocervical trunk).

Fig. 7.17 Arteries of the thoracic wall
Anterior view.

Table 7.5 Arteries of the thoracic wall	
Origin	Branch
Axillary a.	Lateral thoracic a.
	Thoracoacromial a.
Subclavian a.	Posterior intercostal aa. (1st and 2nd; see Fig. 4.1, p. 36)
	Superior thoracic a.
Thoracic aorta	Posterior intercostal aa. (3rd through 12th)
Internal thoracic a.	Anterior intercostal aa.
	Musculophrenic a.
	Superior epigastric a.

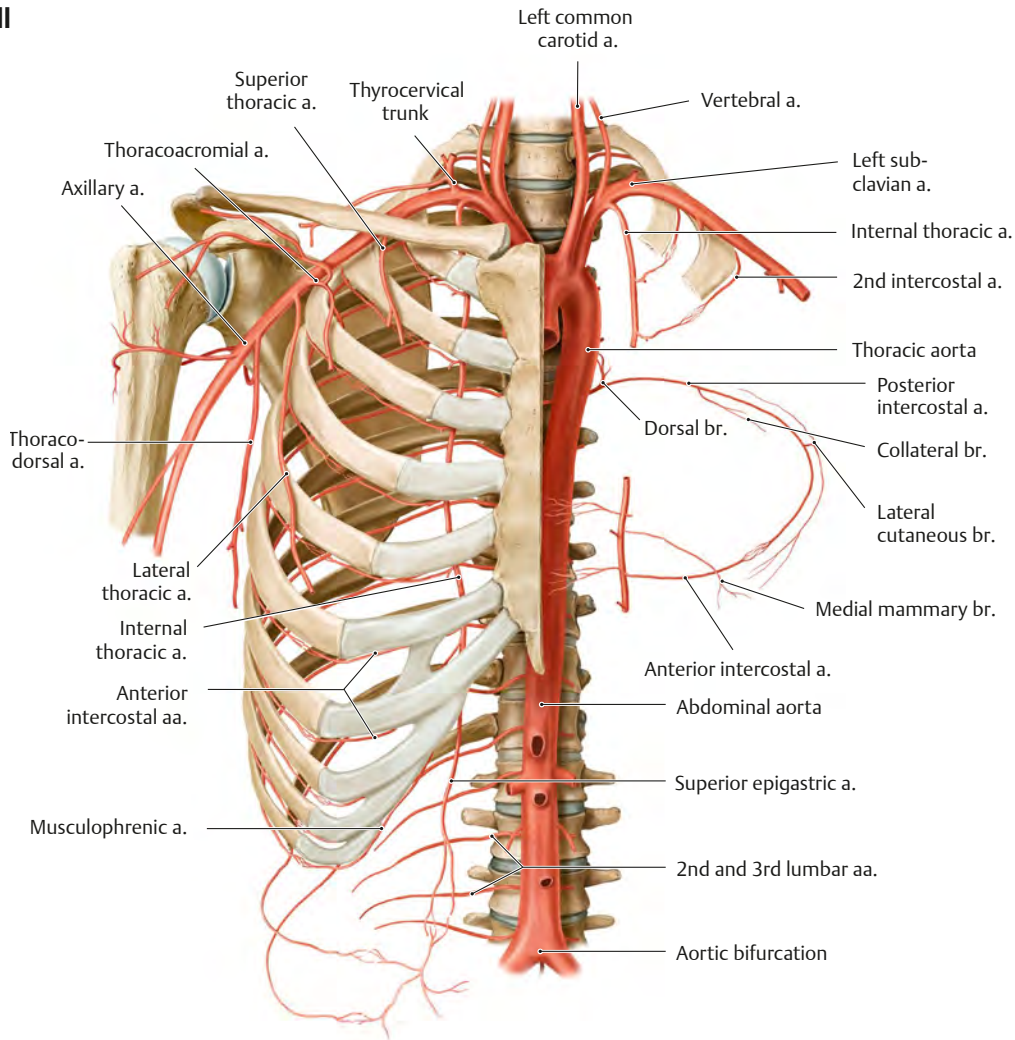


Fig. 7.18 Branches of the intercostal arteries
Superior view.

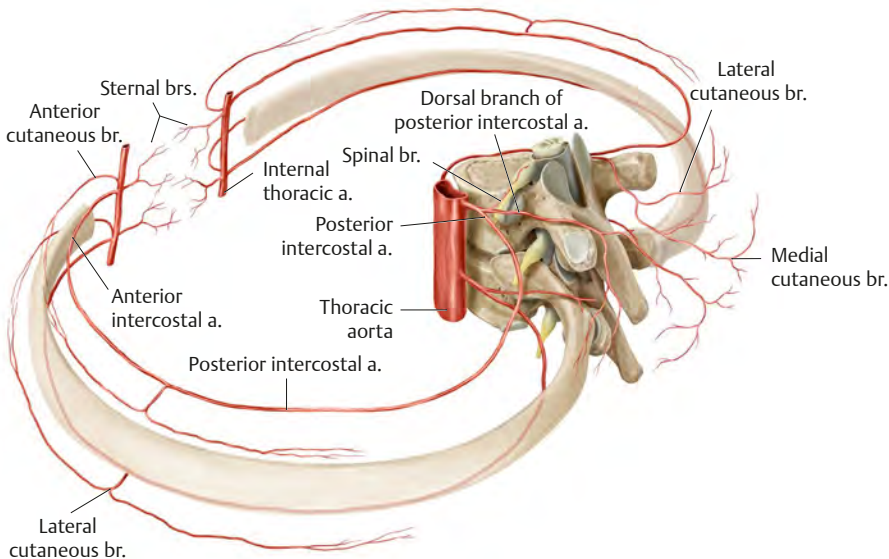
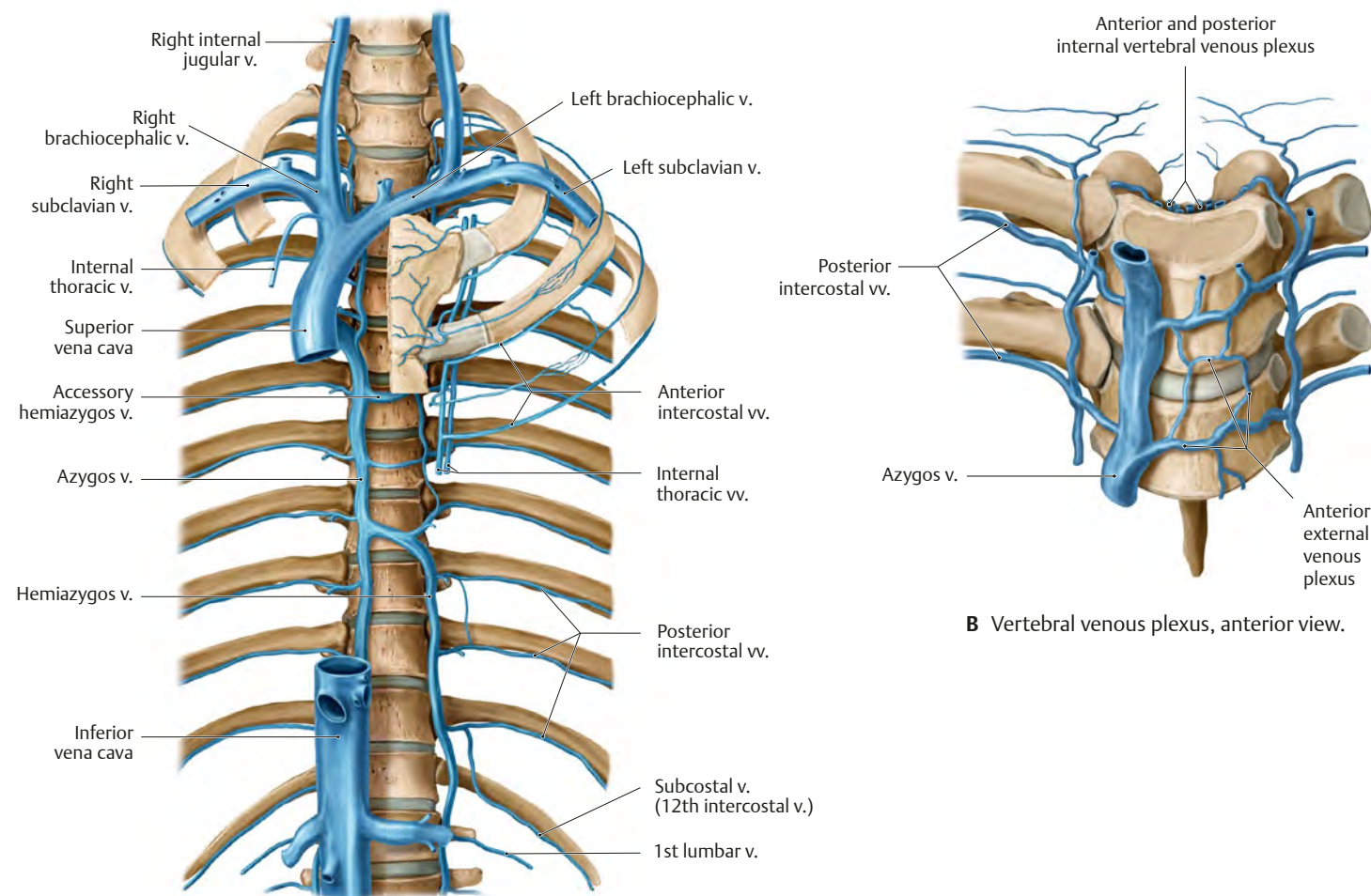


Table 7.6		Branches of the intercostal arteries	
Artery	Branches		Supplies
Posterior intercostal aa.	Dorsal br.	Spinal br.	Spinal cord
		Medial cutaneous br.	Posterior thoracic wall
		Lateral cutaneous br.	
	Collateral br.	Lateral thoracic wall	
Anterior intercostal aa.	Lateral cutaneous br.*		Anterior thoracic wall
*The lateral mammary br. from the lateral cutaneous br. supplies the breast along with the medial mammary br. from the internal thoracic a.			

The intercostal veins drain primarily into the azygos system, but also into the internal thoracic vein. This blood ultimately returns to the heart via the superior vena cava. The intercostal veins follow a similar

course to their arterial counterparts. However, the veins of the vertebral column form an external vertebral venous plexus that traverses the entire length of the spine (see p. 37).

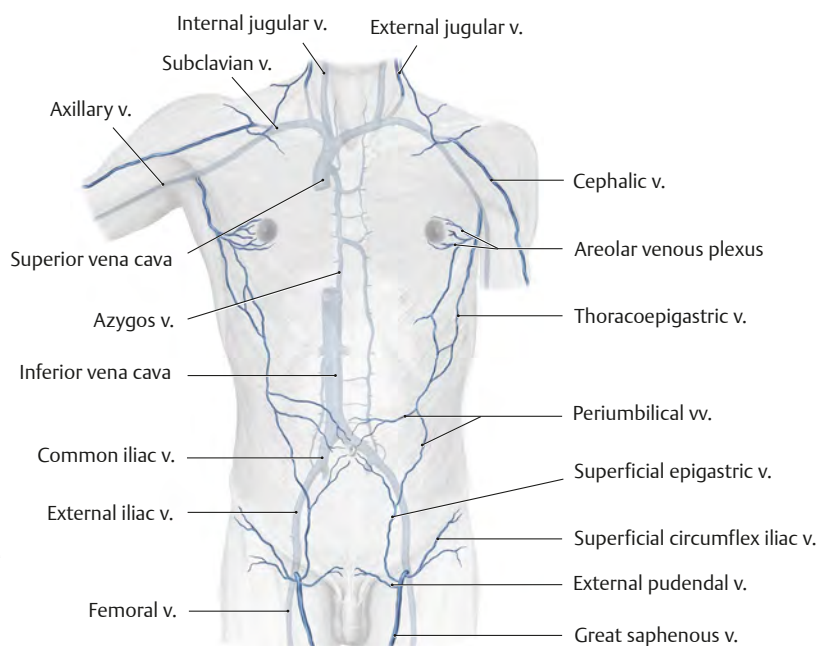
Fig. 7.19 Veins of the thoracic wall



A Anterior view with rib cage opened.

Fig. 7.20 Superficial veins

Anterior view. The thoracoepigastric veins are a potential superficial collateral venous drainage route in the event of superior or inferior vena cava obstruction.



Nerves of the Thoracic Wall

Fig. 7.21 Intercostal nerves

Anterior view. The 1st rib has been removed to reveal the 1st and 2nd intercostal nerves.

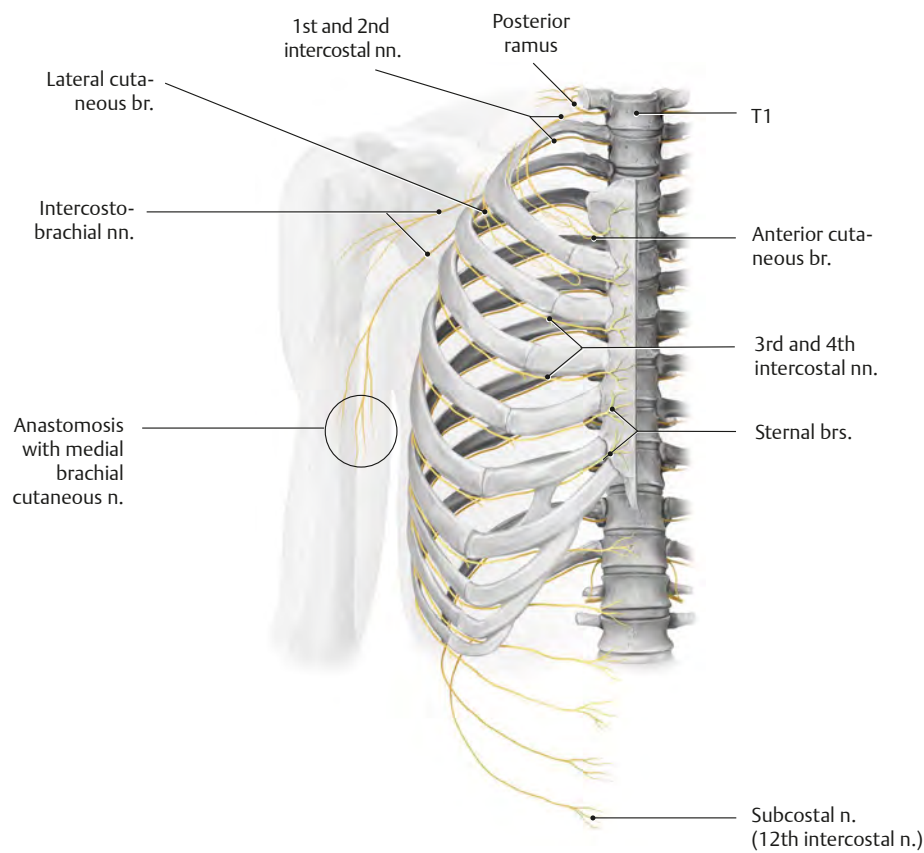


Fig. 7.22 Cutaneous innervation of the thoracic wall

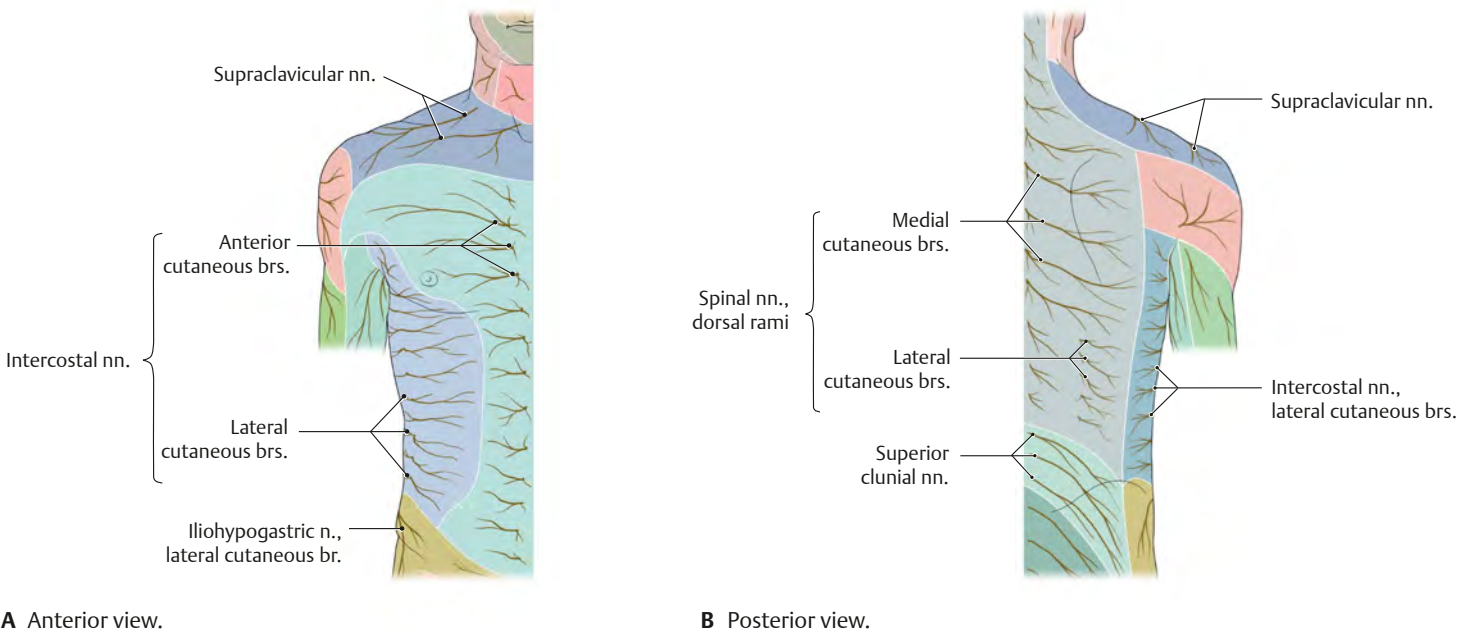
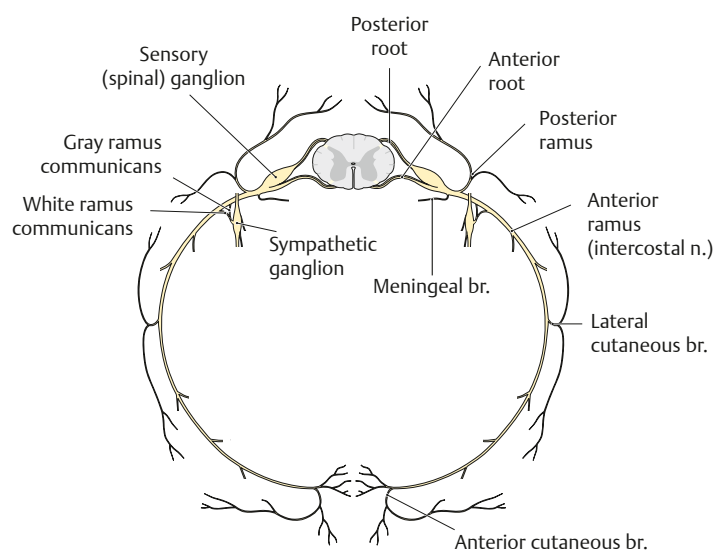
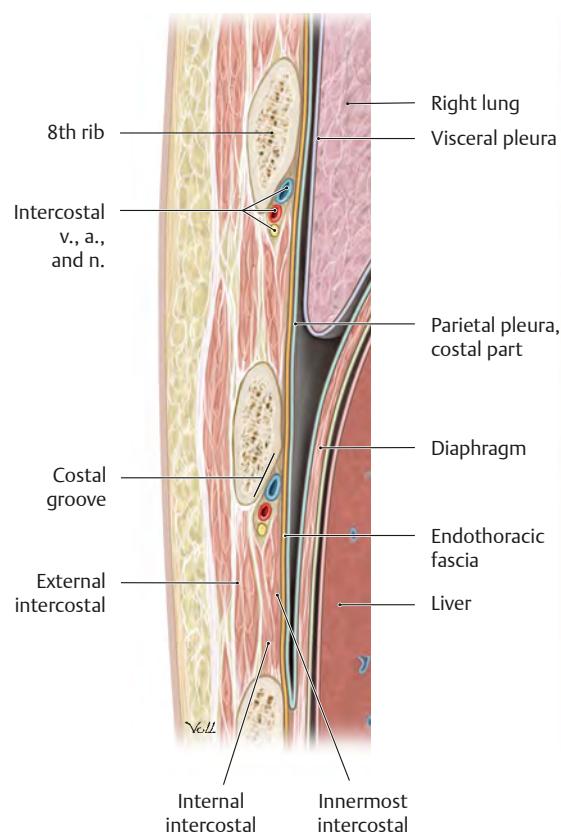


Fig. 7.23 Spinal nerve branches

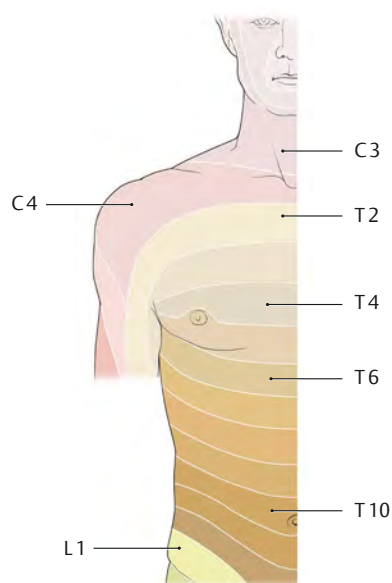
Superior view. The spinal nerve is formed by the union of posterior (dorsal) and anterior (ventral) roots. The posterior root contains sensory fibers and the anterior root contains motor fibers. The spinal nerve and all its subsequent branches are mixed nerves, containing both motor and sensory fibers. The spinal nerve exits the vertebral canal via the intervertebral foramen. Its posterior ramus innervates the skin and intrinsic muscles of the back; its anterior ramus forms the cervical, brachial, lumbar, and sacral plexuses, and the intercostal nerves. See p. 38 for more details.

**Fig. 7.24 Arrangement of intercostal neurovascular bundle**

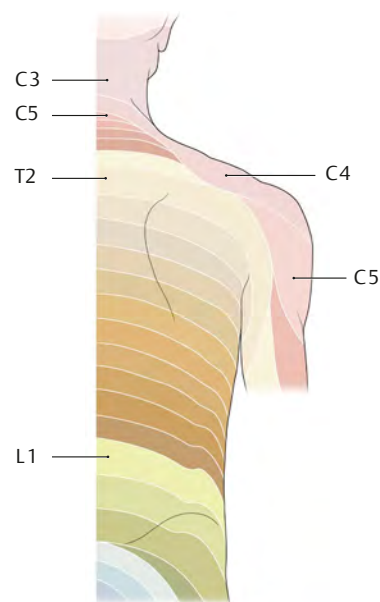
Coronal section, anterior view.

**Fig. 7.25 Dermatomes of the thoracic wall**

Landmarks: T4 generally includes the nipple; T6 innervates the skin over the xiphoid.



A Anterior view.

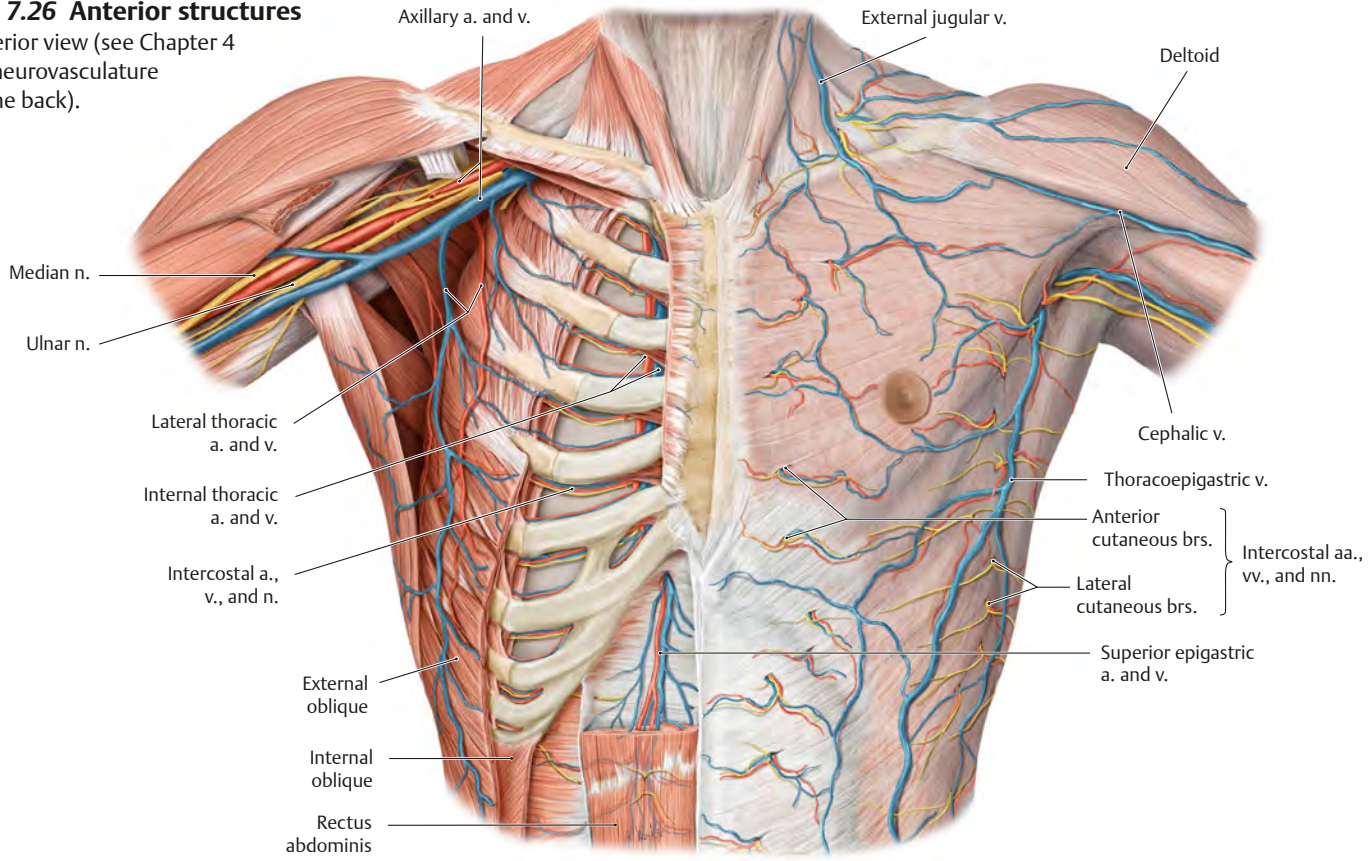


B Posterior view.

Neurovascular Topography of the Thoracic Wall

Fig. 7.26 Anterior structures

Anterior view (see Chapter 4 for neurovasculature of the back).

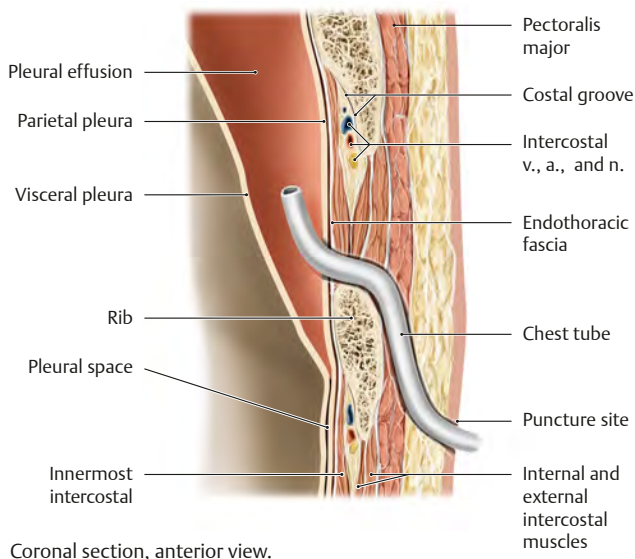


Clinical box 7.1

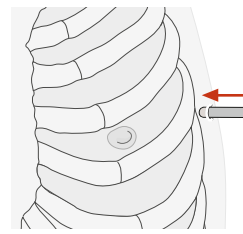
Insertion of a chest tube

Abnormal fluid collection in the pleural space (e.g., pleural effusion due to bronchial carcinoma) may necessitate the insertion of a chest tube. Generally, the optimal puncture site in a sitting patient is at the level of the 4th or 5th intercostal space in the mid to anterior axillary line, immediately behind the

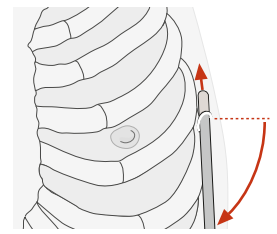
lateral edge of the pectoralis major. The drain should always be introduced at the upper margin of a rib to avoid injuring the intercostal vein, artery, and nerve. See **Clinical box 10.5** on p. 123 for details on collapsed lungs.



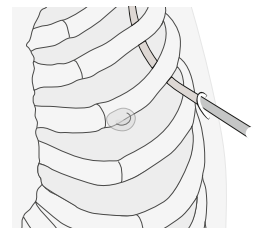
A Coronal section, anterior view.



B Drainage tube is inserted perpendicular to chest wall.



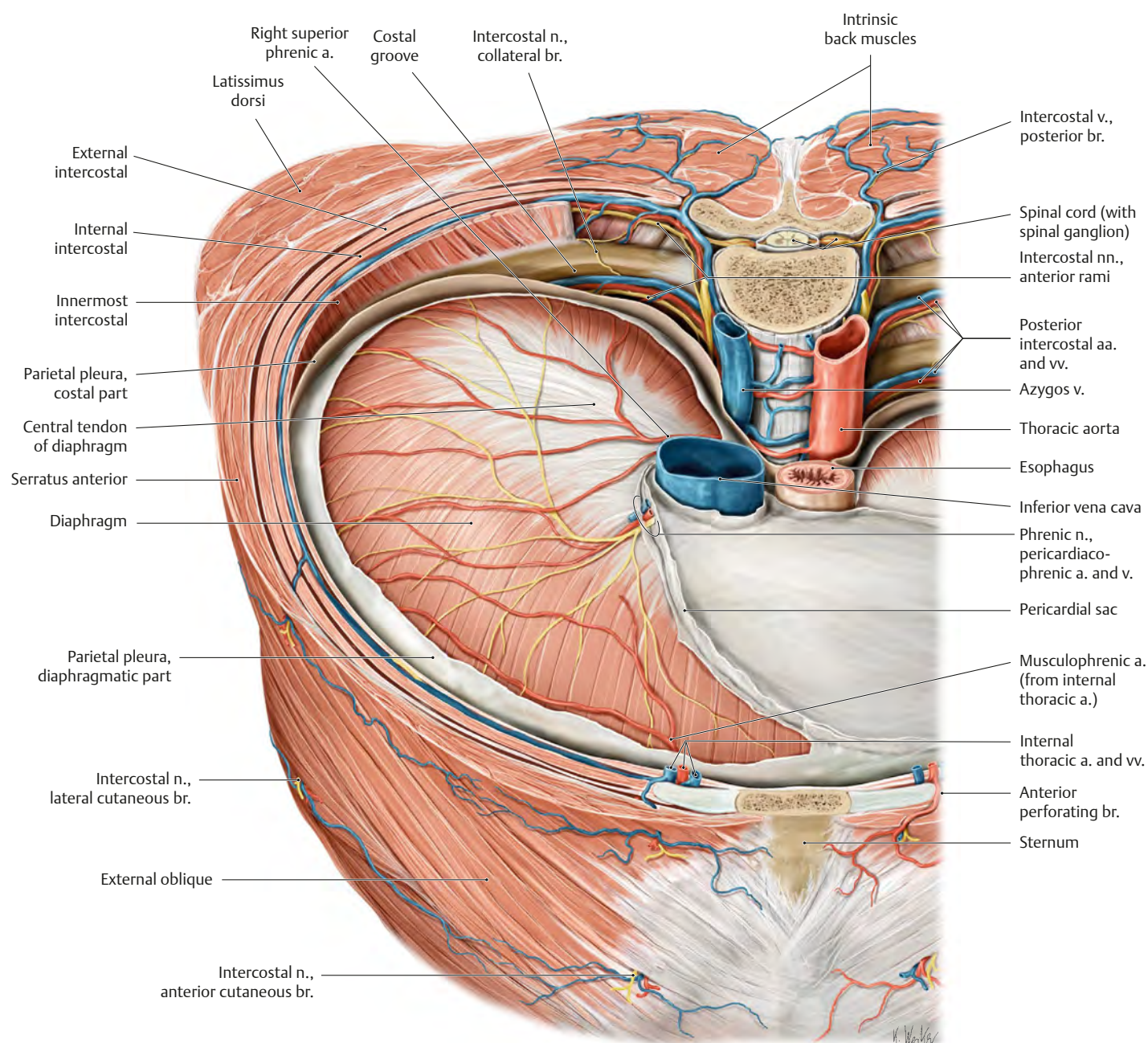
C At ribs, the tube is angled and advanced parallel to the chest wall in the subcutaneous plane.



D At the superior margin of the rib, the tube is passed through the intercostal muscles and advanced into the pleural cavity.

Fig. 7.27 Intercostal structures in cross section

Transverse section, anterosuperior view. The relationship of the intercostal vessels in the costal groove, from superior to inferior, is vein, artery, and nerve (see clinical box, p. 72).



Female Breast

The female breast, a modified sweat gland in the subcutaneous tissue layer, consists of glandular tissue, fibrous stroma, and fat. The breast extends from the 2nd to the 6th rib and is loosely attached to the pec-

toral, axillary, and superficial abdominal fascia by connective tissue. The breast is additionally supported by suspensory ligaments. An extension of the breast tissue into the axilla, the axillary tail, is generally present.

Fig. 7.28 Female breast

Right breast, anterior view.

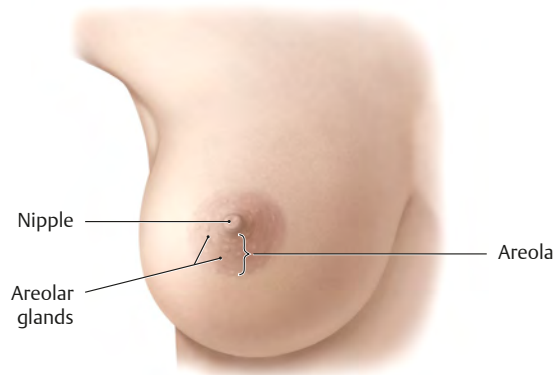


Fig. 7.29 Mammary ridges

Rudimentary mammary glands form in both sexes along the mammary ridges. Occasionally, these may persist in humans to form accessory nipples (*polythelia*), although only thoracic nipples normally remain.



Fig. 7.30 Blood supply to the breast

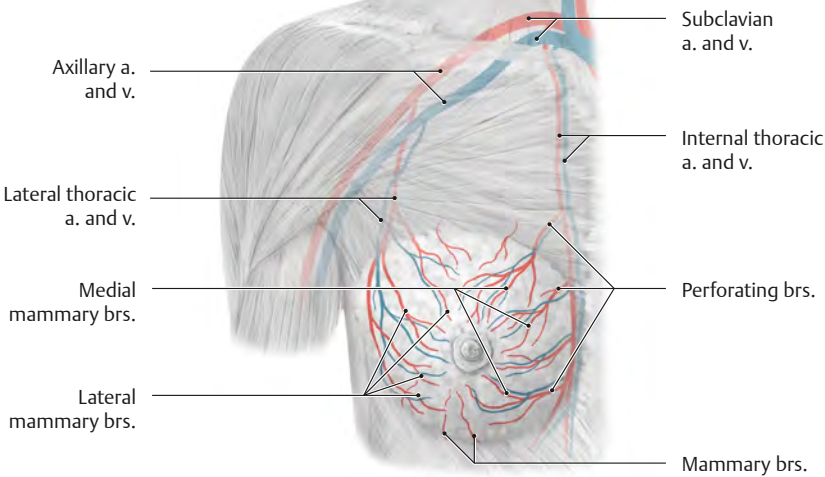
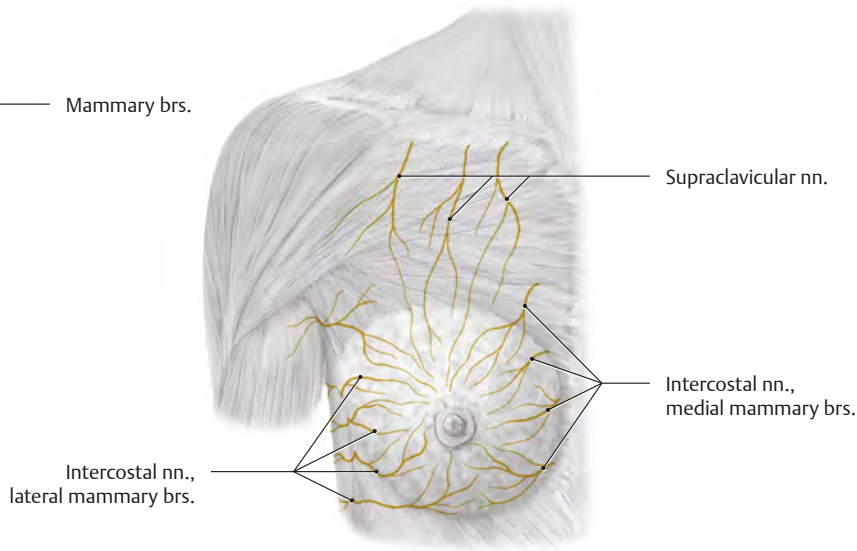


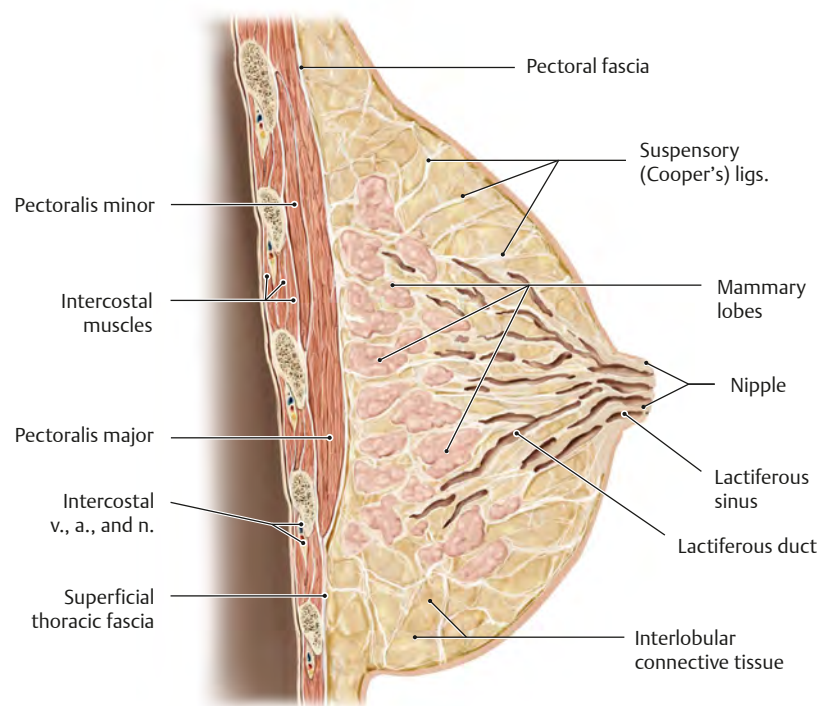
Fig. 7.31 Sensory innervation of the breast



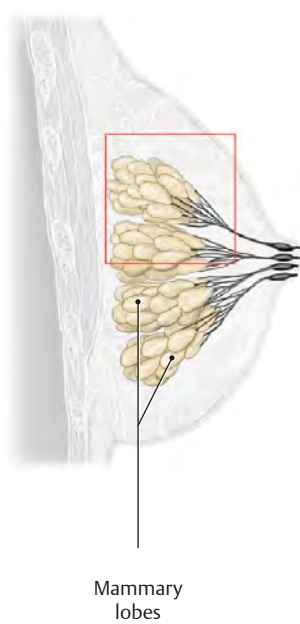
The glandular tissue is composed of 10 to 20 individual lobes, each with its own lactiferous duct. The gland ducts open on the elevated nipple at the center of the pigmented areola. Just proximal to the duct opening is

a dilated portion called the lactiferous sinus. Areolar elevations are the openings of the areolar glands (sebaceous). The glands and lactiferous ducts are surrounded by firm, fibrofatty tissue with a rich blood supply.

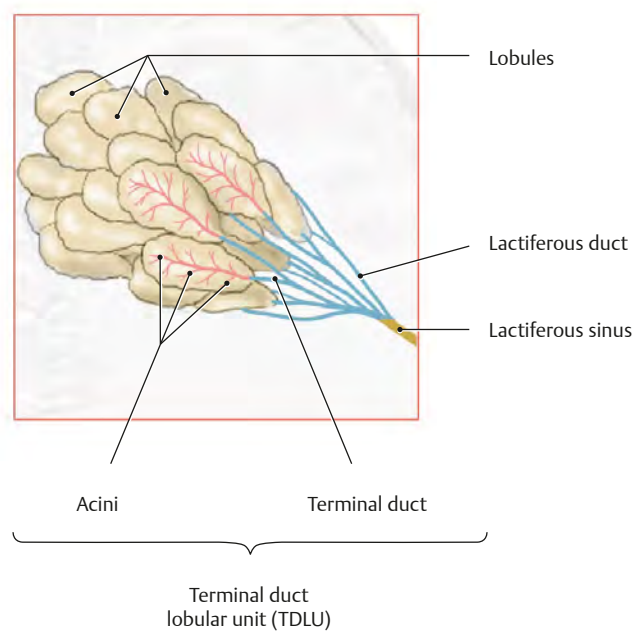
Fig. 7.32 Structures of the breast



A Sagittal section along midclavicular line.



B Duct system and portions of a lobe, sagittal section. In the nonlactating breast (shown here), the lobules contain clusters of rudimentary acini.

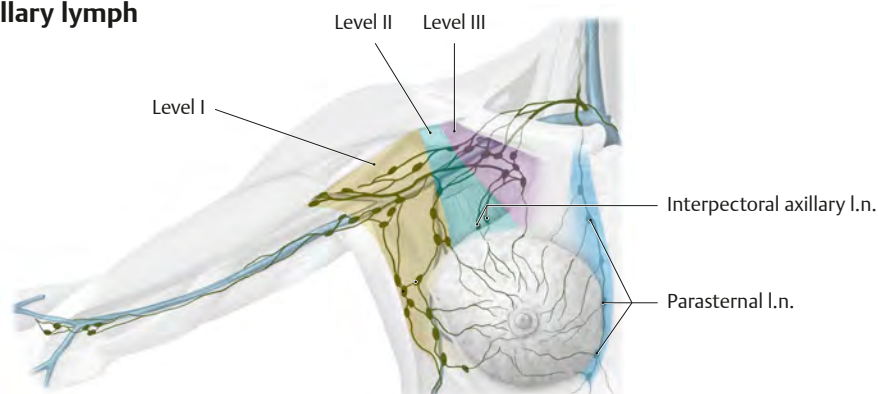


C Terminal duct lobular unit (TDLU). The clustered acini composing the lobule empty into a terminal ductule; these structures are collectively known as the TDLU.

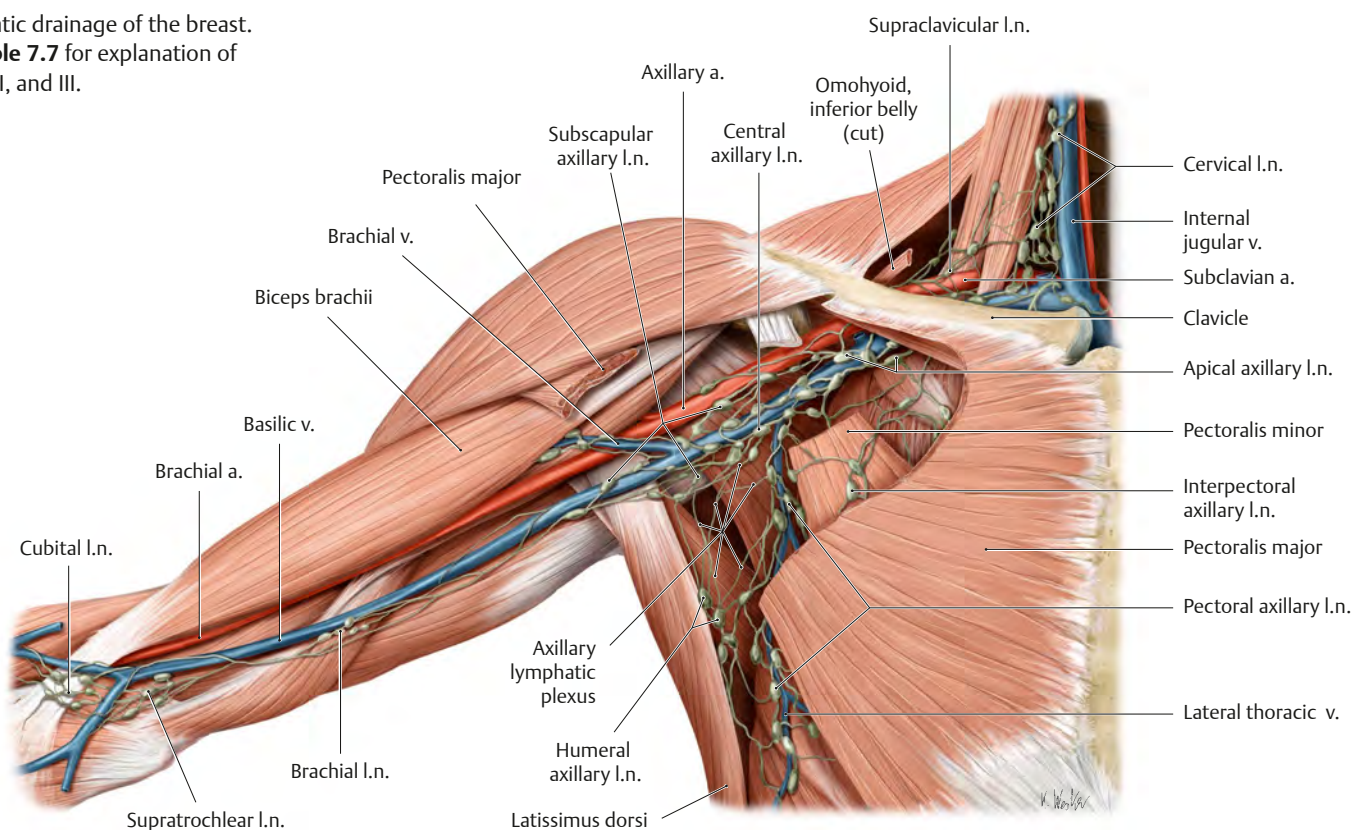
The lymphatic vessels of the breast (not shown) are divided into three systems: superficial, subcutaneous, and deep. These drain primarily into the axillary lymph nodes, which are classified based on their

relationship to the pectoralis minor (**Table 7.7**). The medial portion of the breast is drained by the parasternal lymph nodes, which are associated with the internal thoracic vessels.

Fig. 7.33 Axillary lymph nodes



A Lymphatic drainage of the breast. See **Table 7.7** for explanation of level I, II, and III.



B Anterior view.

Table 7.7 Levels of axillary lymph nodes

Level		Position	Lymph nodes (l.n.)
I	Lower axillary group	Lateral to pectoralis minor	Pectoral axillary l.n.
			Subscapular axillary l.n.
			Humeral axillary l.n.
II	Middle axillary group	Along pectoralis minor	Central axillary l.n.
			Interpectoral axillary l.n.
III	Upper infraclavicular group	Medial to pectoralis minor	Apical axillary l.n.

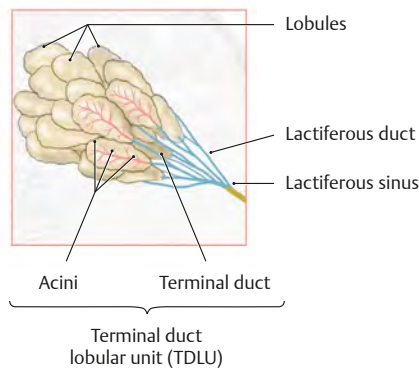


Clinical box 7.2

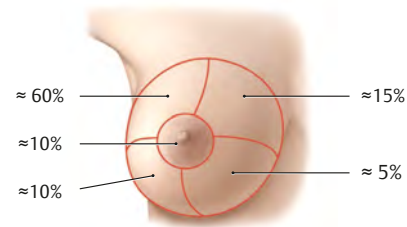
Breast cancer

Stem cells in the intralobular connective tissue give rise to tremendous cell growth, necessary for duct system proliferation and acini differentiation. This

makes the terminal duct lobular unit (TDLU) the most common site of origin of malignant breast tumors.



A Terminal duct lobular unit.

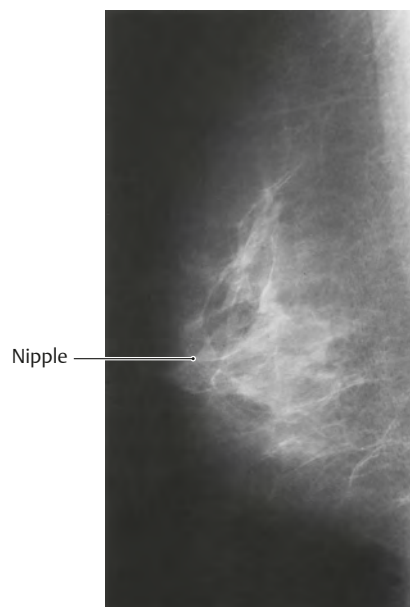


B Origin of malignant tumors by quadrant.

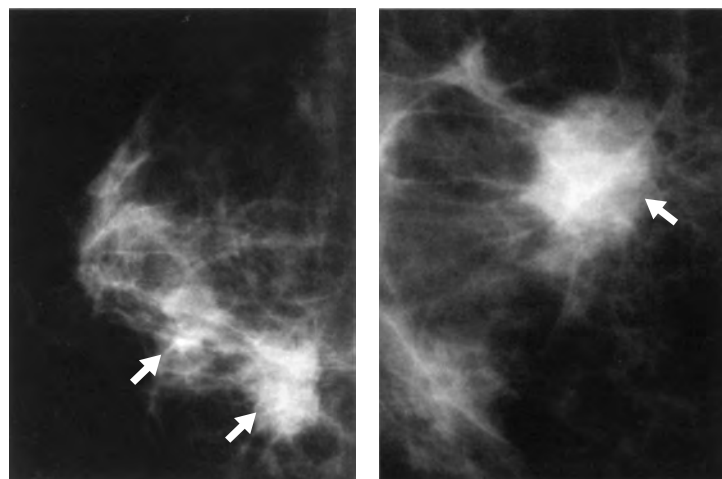
Tumors originating in the breast spread via the lymphatic vessels. The deep system of lymphatic drainage (level III) is of particular importance, although the parasternal lymph nodes provide a route by which tumor cells may spread across the midline. The survival rate in breast cancer correlates most strongly with the number of lymph nodes involved at the axillary nodal level. Metastatic involvement is gauged through scintigraphic mapping

with radiolabeled colloids (technetium [Tc] 99m sulfur microcolloid). The downstream sentinel node is the first to receive lymphatic drainage from the tumor and is therefore the first to be visualized with radiolabeling. Once identified, it can then be removed (via *sentinel lymphadenectomy*) and histologically examined for tumor cells. This method is 98% accurate in predicting the level of axillary nodal involvement.

Metastatic involvement	5-year survival rate
Level I	65%
Level II	31%
Level III	~0%



C Normal mammogram.



D Mammogram of invasive ductal carcinoma (irregular white areas, arrows). The large lesion has changed the architecture of the neighboring breast tissue.

8 Thoracic Cavity

Divisions of the Thoracic Cavity

The thoracic cavity is divided into three large spaces: the mediastinum (p. 90) and the two pleural (pulmonary) cavities (p. 112).

Fig. 8.1 Thoracic cavity
Coronal section, anterior view.

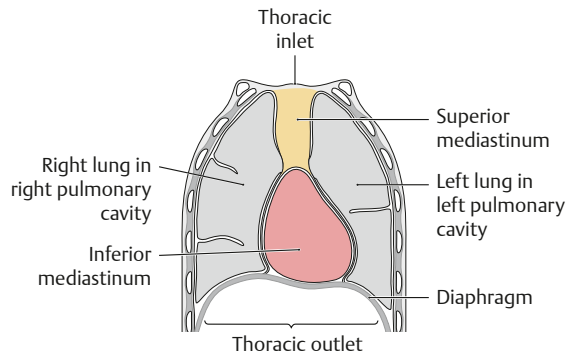
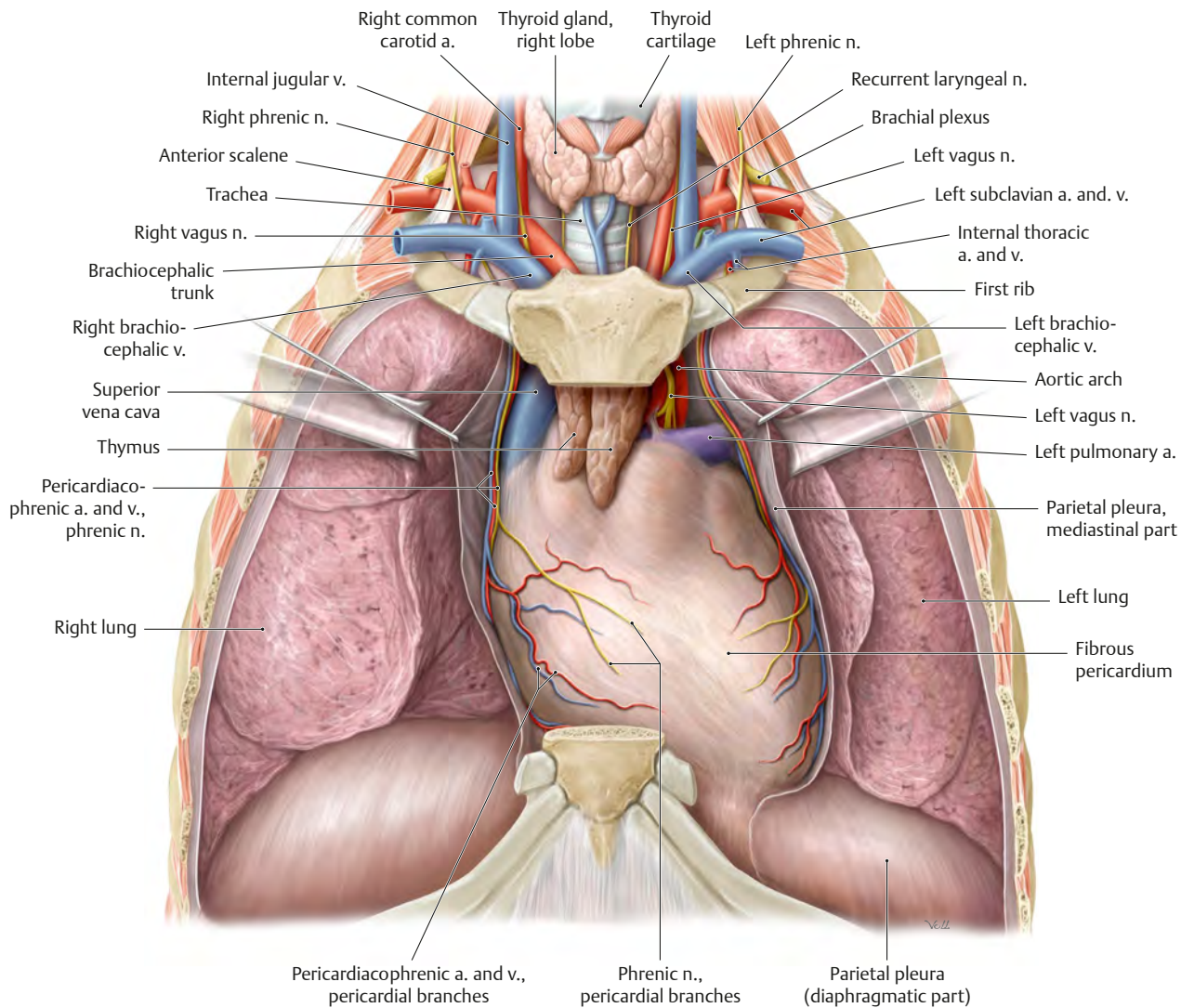
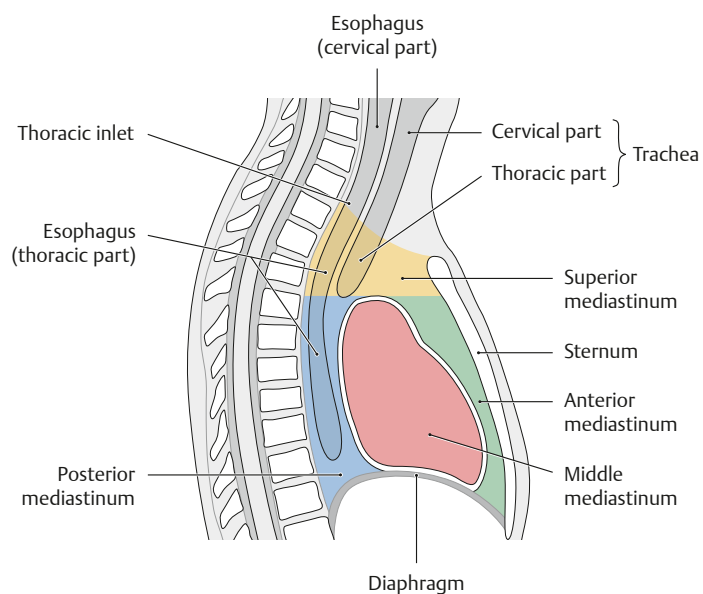
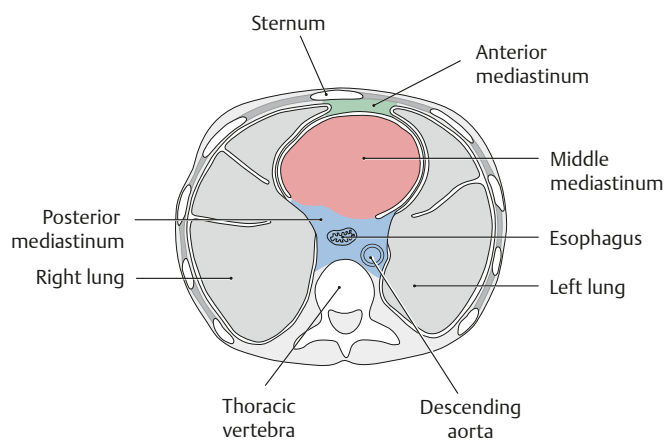


Table 8.1		Major structures of the thoracic cavity	
Mediastinum	Superior mediastinum		Thymus, great vessels, trachea, esophagus, and thoracic duct
	Inferior mediastinum	Anterior	Thymus (especially in children)
		Middle	Heart, pericardium, and roots of great vessels
		Posterior	Thoracic aorta, thoracic duct, esophagus, and azygos venous system
Pulmonary cavities	Right pulmonary cavity		Right lung
	Left pulmonary cavity		Left lung

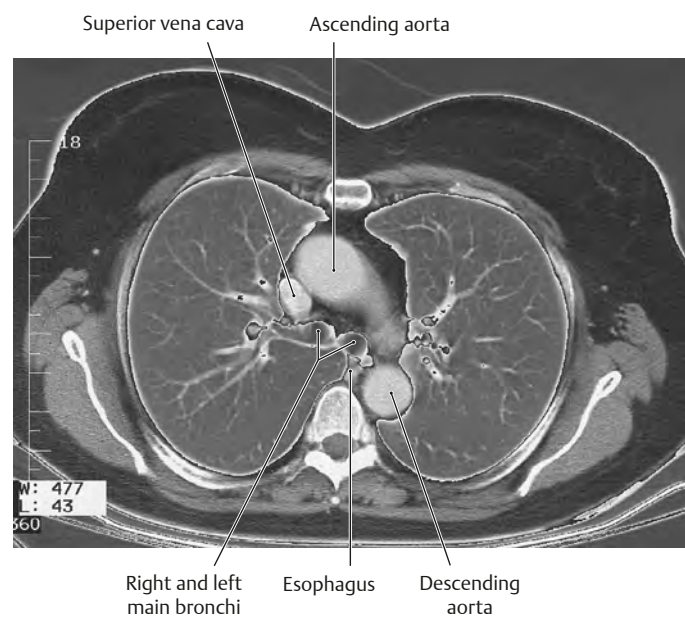
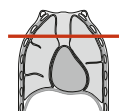
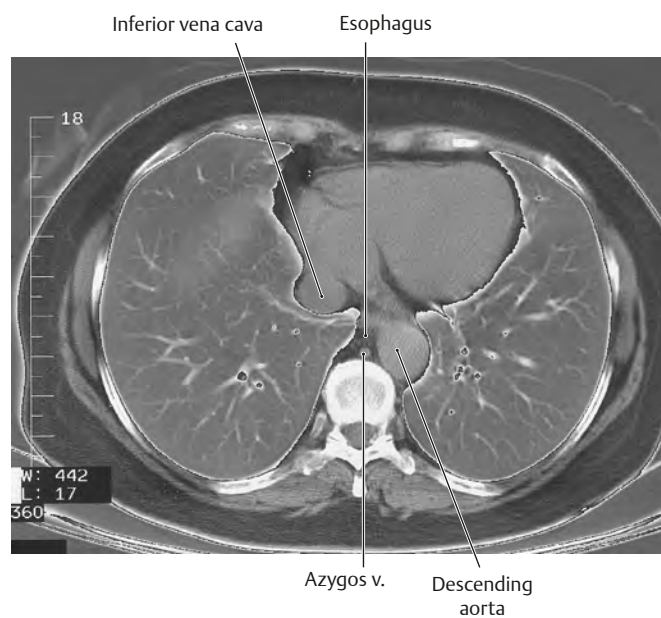
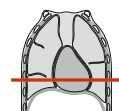
A Divisions of the thoracic cavity.



B Opened thoracic cavity. *Removed:* Thoracic wall; connective tissue of anterior mediastinum.

Fig. 8.2 Divisions of the mediastinum**A** Midsagittal section, lateral view.**B** Transverse section, inferior view.**Fig. 8.3 Transverse sections of the thorax**

Computed tomography (CT) scan of thorax, inferior view.

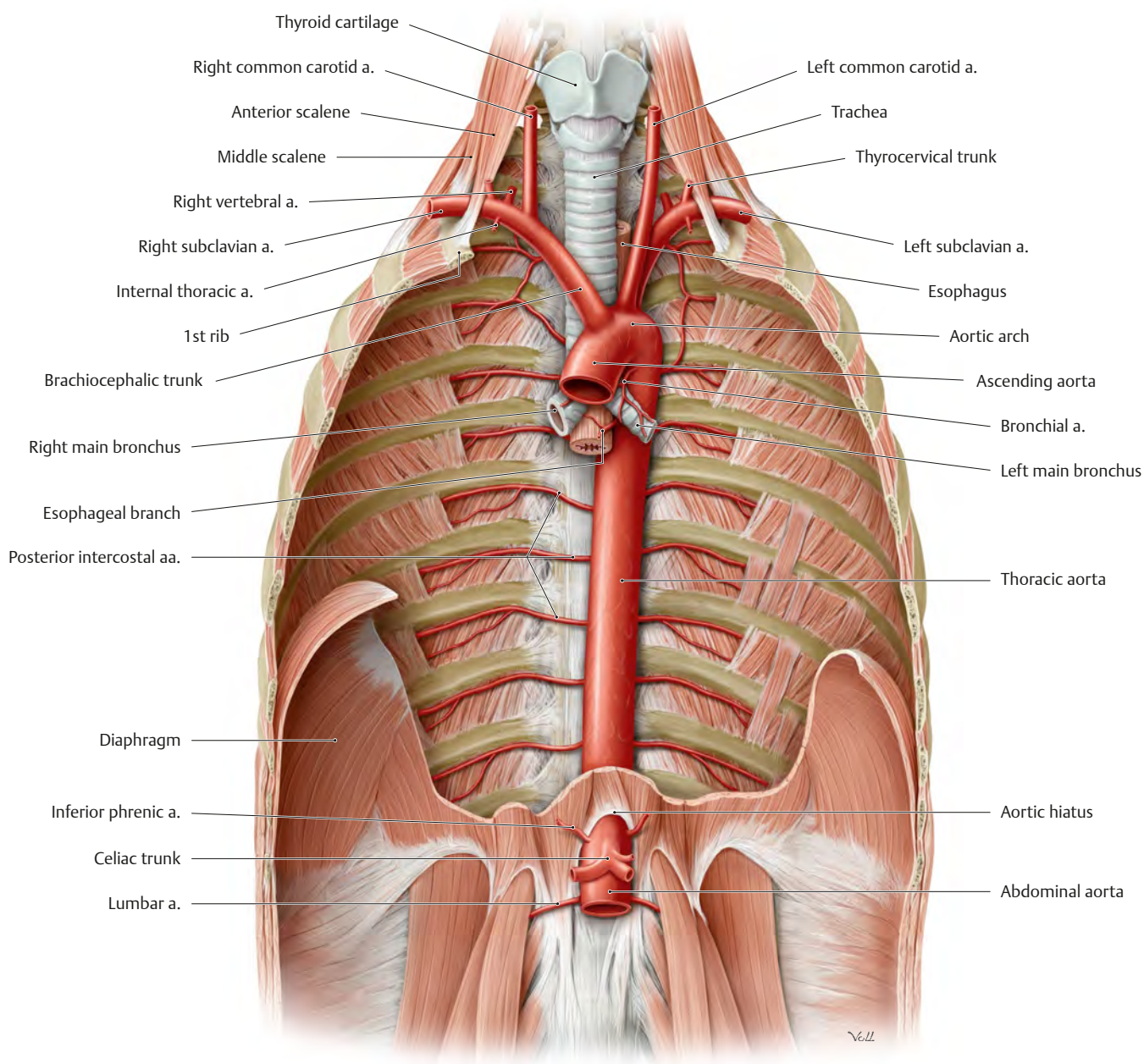
**A** Superior mediastinum.**B** Inferior mediastinum.

Arteries of the Thoracic Cavity

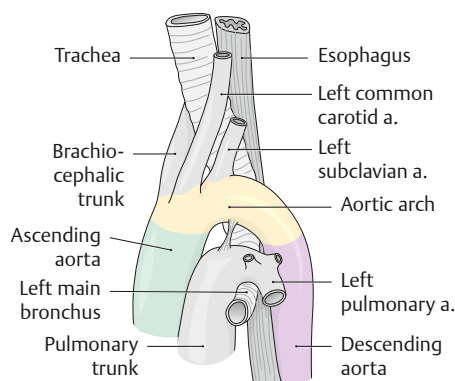
The arch of the aorta has three major branches: the brachiocephalic trunk, left common carotid artery, and left subclavian artery. After the aortic arch, the aorta begins its descent, becoming the thoracic aorta

at the level of the sternal angle and the abdominal aorta once it passes through the aortic hiatus in the diaphragm.

Fig. 8.4 Thoracic aorta



A Thoracic aorta in situ, anterior view. *Removed:* Heart, lungs, portions of diaphragm.



B Parts of the aorta, left lateral view. Note: The aortic arch begins and ends at the level of the sternal angle (see p. 58).

Table 8.2 Branches of the thoracic aorta

The thoracic organs are supplied by direct branches from the thoracic aorta, as well as indirect branches from the subclavian arteries.

Part of aorta	Branches		Region supplied
○ Ascending aorta	Right and left coronary aa.		Heart
○ Arch of aorta	Brachiocephalic trunk	Right subclavian a.	See left subclavian a.
		Right common carotid a.	
	Left common carotid a.		Head and neck
	Left subclavian a.	Vertebral a.	
		Anterior intercostal aa.	Anterior chest wall
		Thymic brs.	Thymus
		Mediastinal brs.	Posterior mediastinum
		Pericardiophrenic a.	Pericardium, diaphragm
		Thyrocervical trunk	Esophagus, trachea, thyroid gland
		Costocervical trunk	Superior intercostal a.
○ Descending aorta	Visceral brs.		Bronchi, trachea, esophagus
	Parietal brs.	Posterior intercostal aa.	Posterior chest wall
		Superior phrenic aa.	Diaphragm

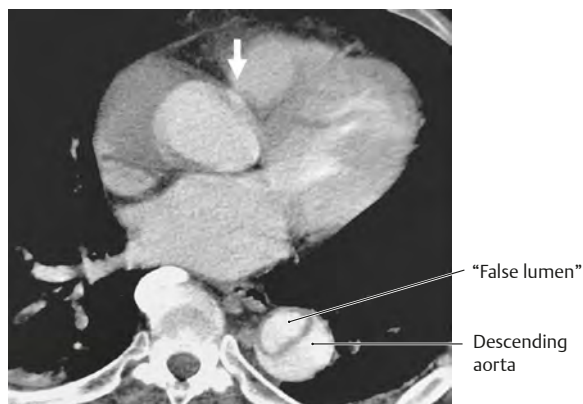


Clinical box 8.1

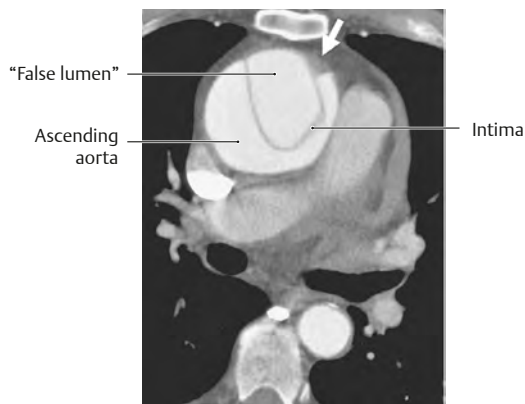
Aortic dissection

A tear in the inner wall (intima) of the aorta allows blood to separate the layers of the aortic wall, creating a “false lumen” and potentially resulting in life-threatening aortic rupture. Symptoms are dyspnea (shortness of breath) and sudden onset of excruciating pain. Acute aortic dissections occur most often in the ascending aorta and generally require surgery. More distal

aortic dissections may be treated conservatively, provided there are no complications (e.g., obstruction of blood supply to the organs, in which case a stent may be inserted to restore perfusion). Aortic dissections occurring at the base of a coronary artery may cause myocardial infarction.



A Aortic dissection. Parts of the intima are still attached to the connective tissue in the wall of the aorta (arrow).



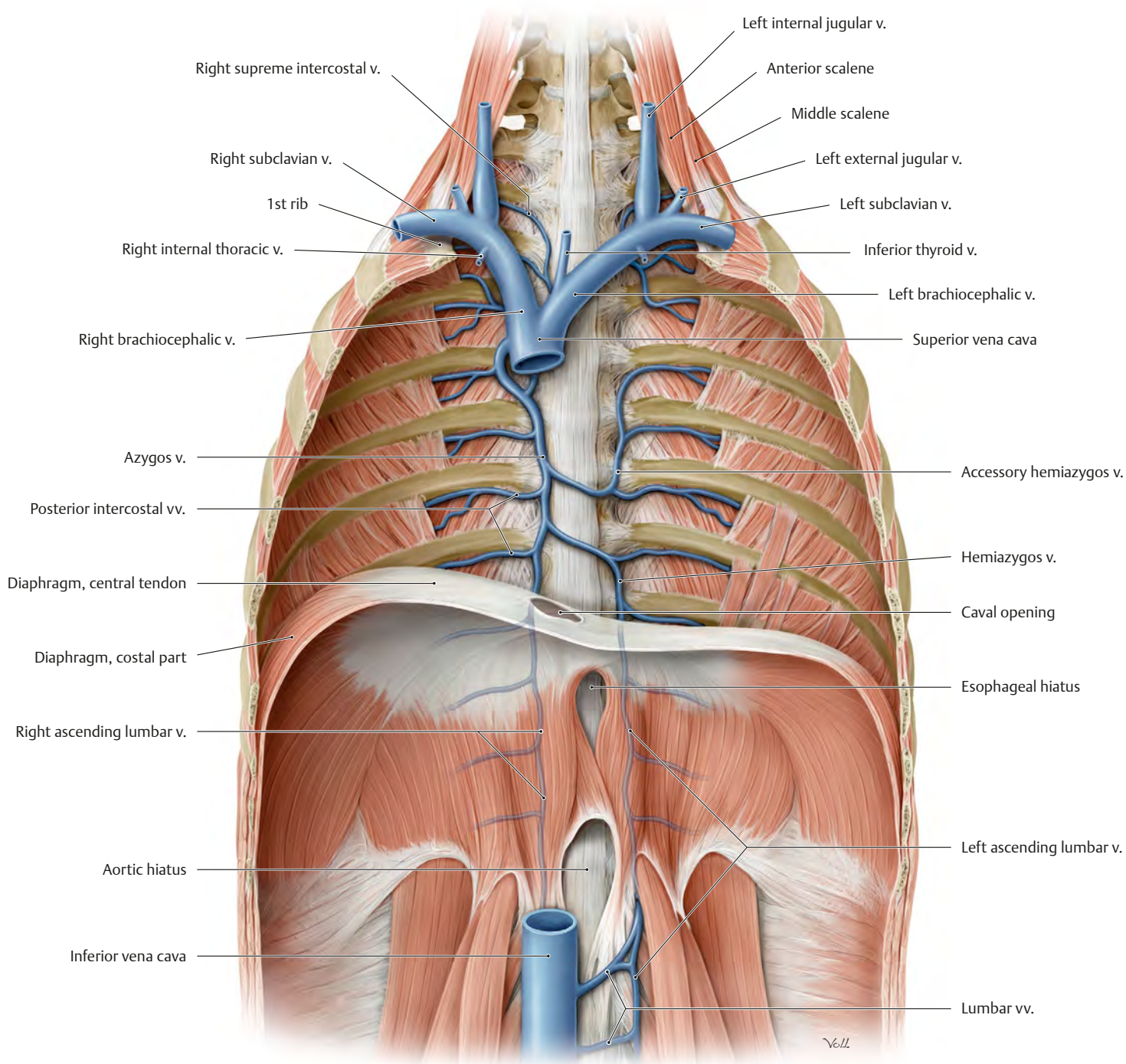
B The flow in the coronary arteries is intact (arrow).

Veins of the Thoracic Cavity

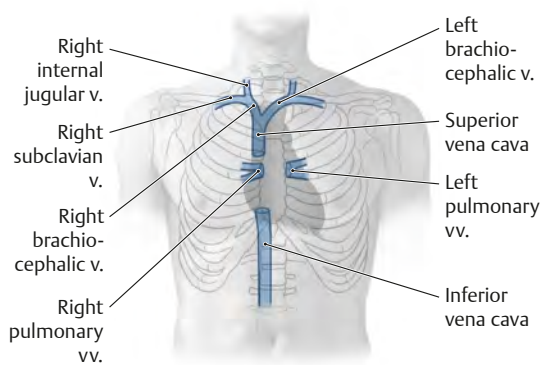
The superior vena cava is formed by the union of the two brachiocephalic veins at the level of the T2–T3 junction. It receives blood

drained by the azygos system (the inferior vena cava has no tributaries in the thorax).

Fig. 8.5 Superior vena cava and azygos system



A Veins of the thoracic cavity (viscera removed), anterior view of opened thorax (posterior thoracic wall).



B Projection of venae cavae onto chest, anterior view.

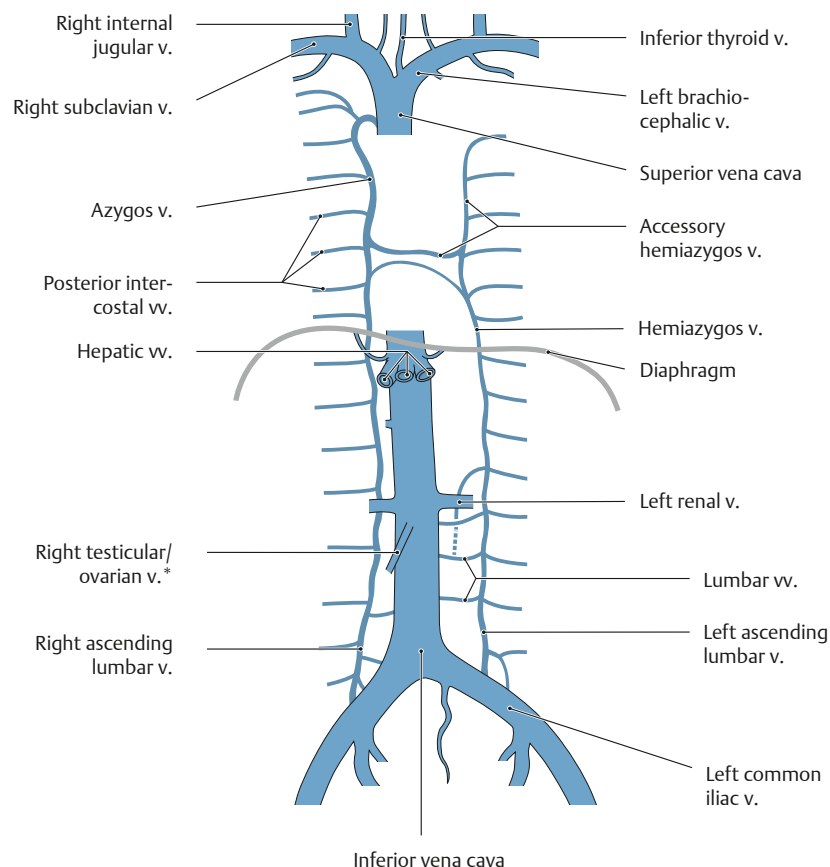
Table 8.3

Thoracic tributaries of the superior vena cava

Major vein	Tributaries		Region drained
Brachiocephalic vv.	Inferior thyroid v.		Esophagus, trachea, thyroid gland
	Internal jugular vv.		Head, neck, upper limb
	External jugular vv.		
	Subclavian vv.		
	Supreme intercostal vv.		
	Pericardial vv.		
	Left superior intercostal v.		
Azygos system (left side: accessory hemiazygos v.; right side: azygos v.)	Visceral brs.		Trachea, bronchi, esophagus
	Parietal brs.	Posterior intercostal vv.	Inner chest wall and diaphragm
		Superior phrenic vv.	
		Right superior intercostal v.	
Internal thoracic v.	Thymic vv.		Thymus
	Mediastinal tributaries		Posterior mediastinum
	Anterior intercostal vv.		Anterior chest wall
	Pericardiophrenic v.		Pericardium
	Musculophrenic v.		Diaphragm
Note: Structures of the superior mediastinum may also drain directly to the brachiocephalic veins via the tracheal, esophageal, and mediastinal veins.			

Note: Structures of the superior mediastinum may also drain directly to the brachiocephalic veins via the tracheal, esophageal, and mediastinal veins.

Fig. 8.6 Azygos system
Anterior view.



*The left testicular/ovarian vein drains to the left renal vein.

Lymphatics of the Thoracic Cavity

The body's chief lymph vessel is the thoracic duct. Beginning in the abdomen at the level of L1 at the *cisterna chyli*, the thoracic duct empties into the junction of the left internal jugular and subclavian

veins. The right lymphatic duct drains to the right junction of the internal jugular and subclavian veins.

Fig. 8.7 Lymphatic trunks in the thorax

Anterior view of opened thorax.

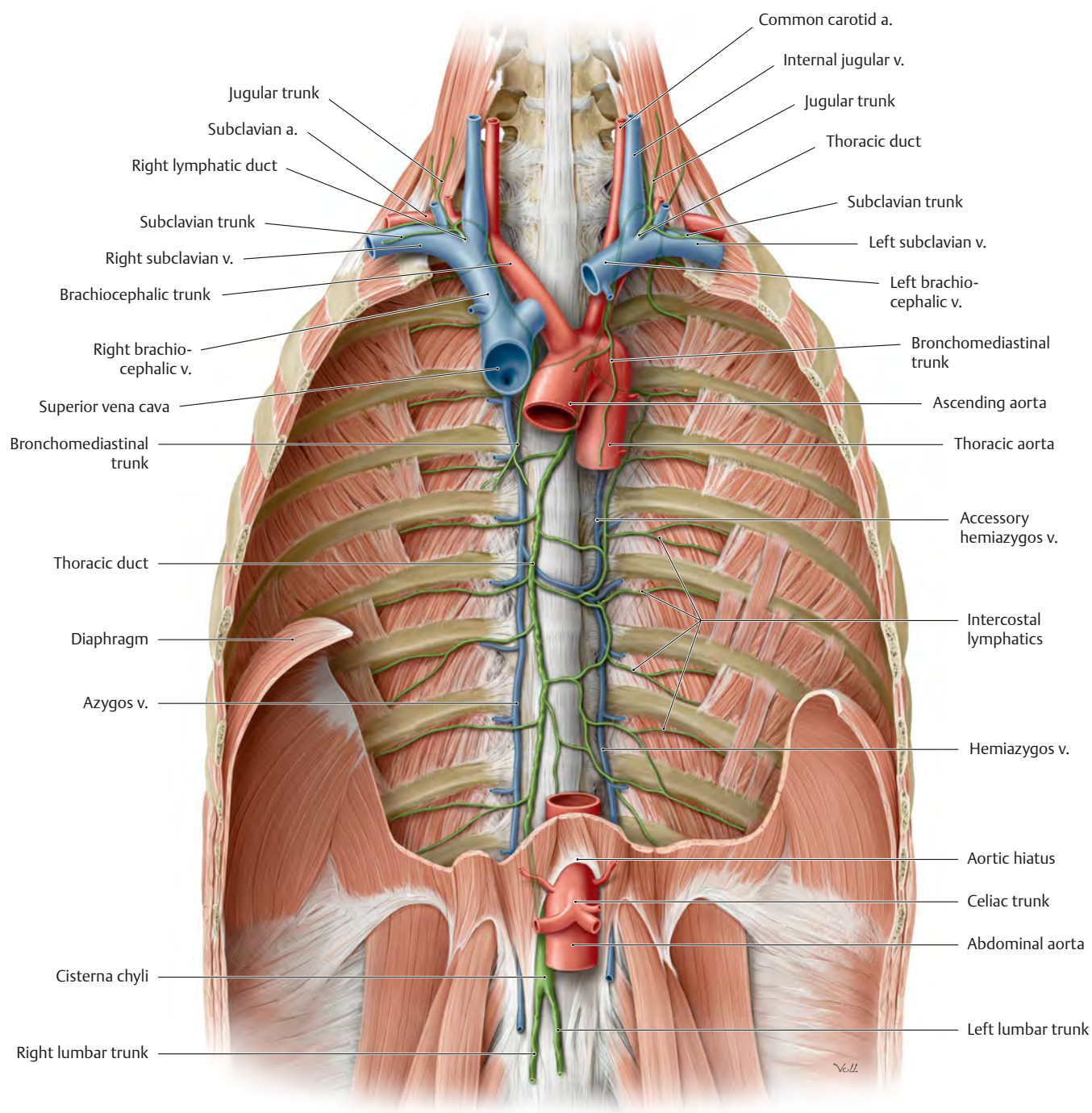
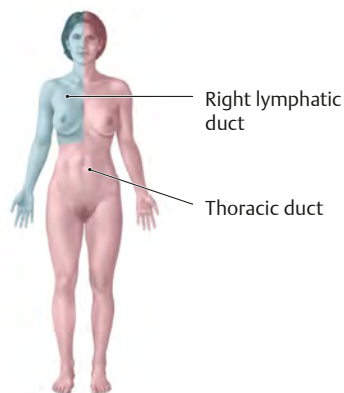
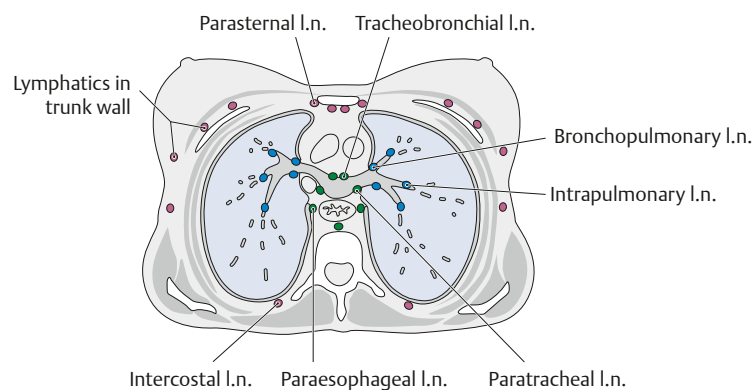
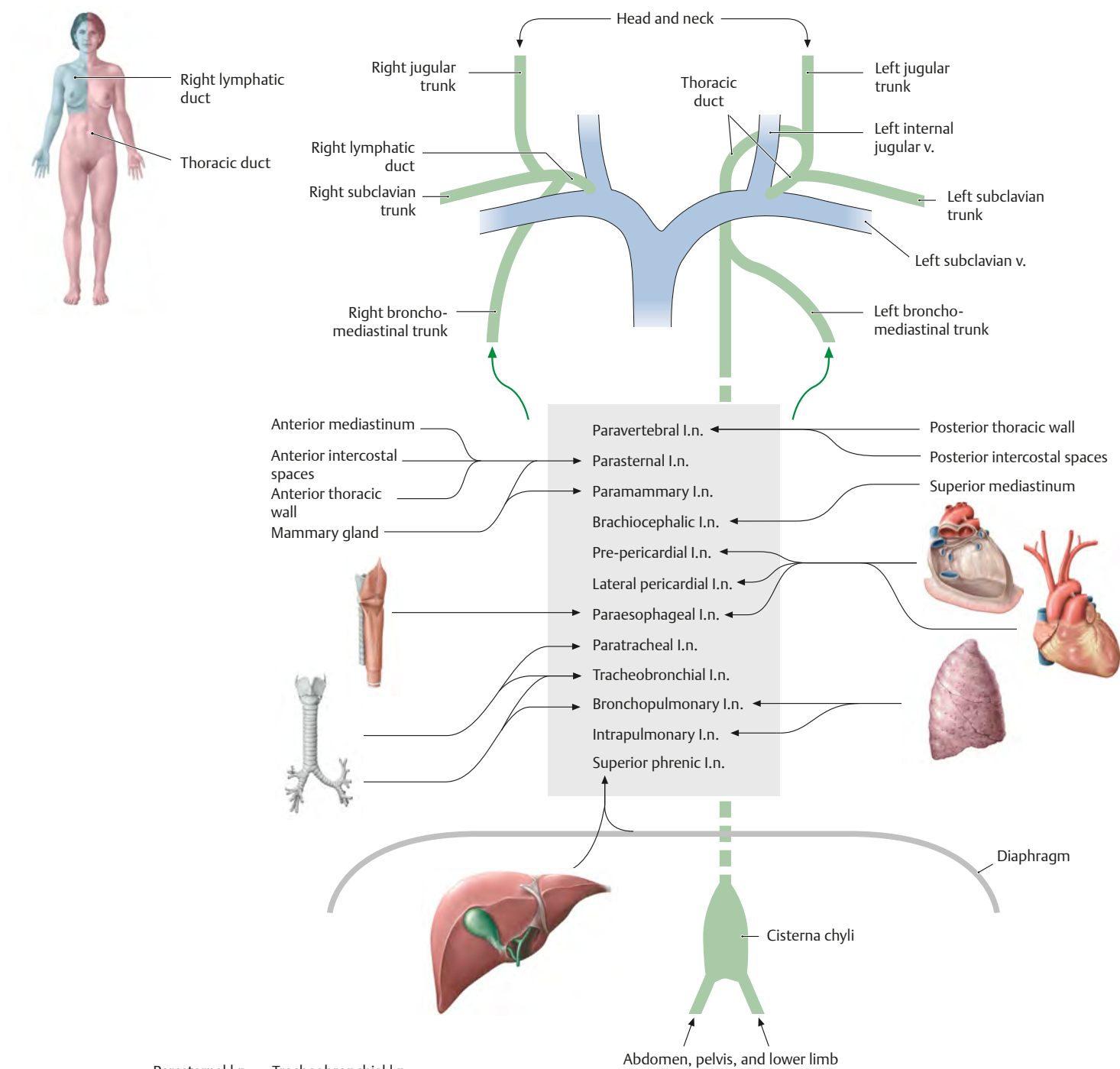


Fig. 8.8 Lymphatic drainage pattern**Fig. 8.9** Lymphatic pathways in the thorax**Fig. 8.10** Thoracic lymph nodes

Transverse section at the level of the tracheal bifurcation (T4–T5), superior view. The thoracic lymph nodes can be divided into three broad groups: nodes of the thoracic wall (pink), pulmonary nodes (blue), and mediastinal nodes (green). For details of lymphatics of the mediastinum, see pp. 110–111.

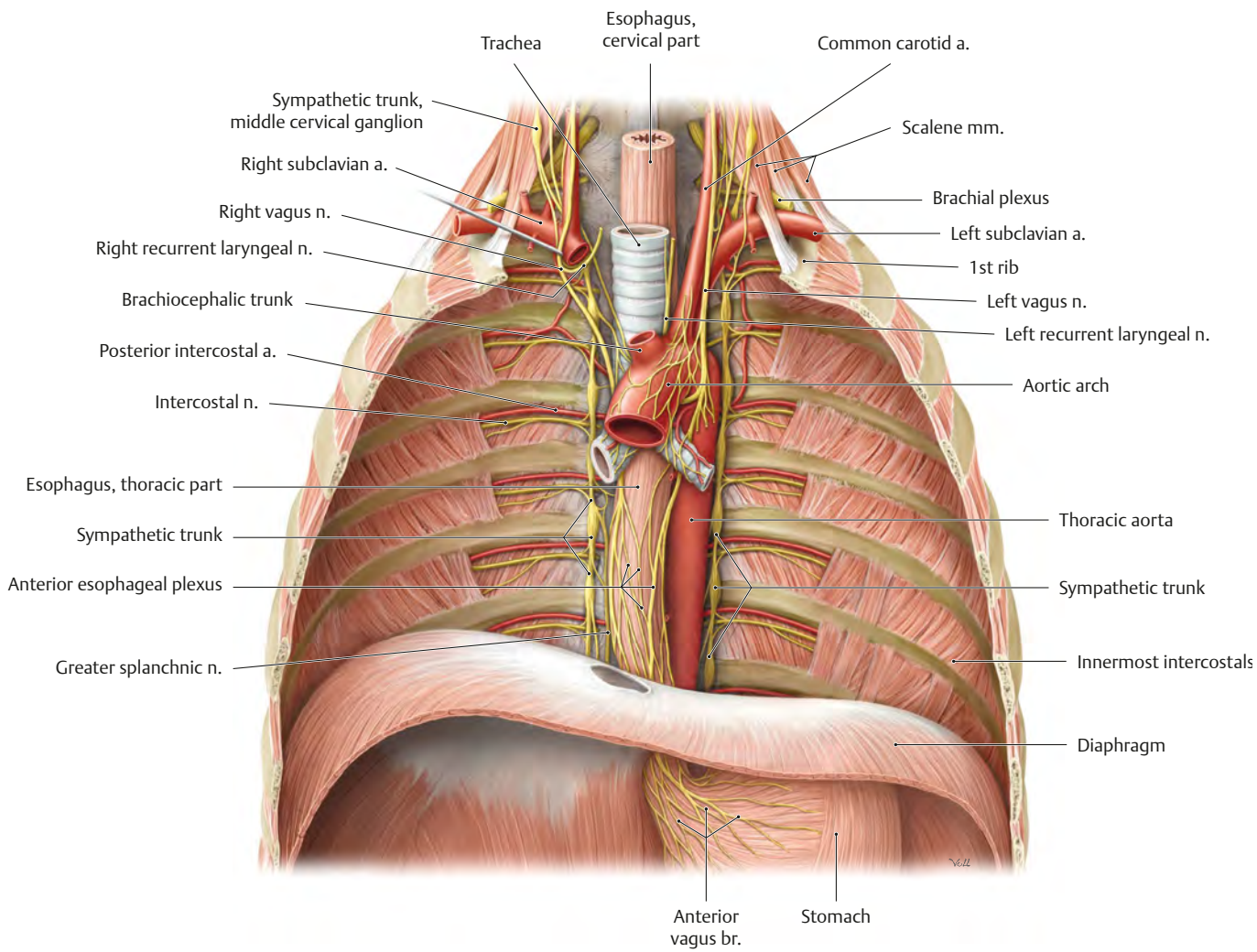
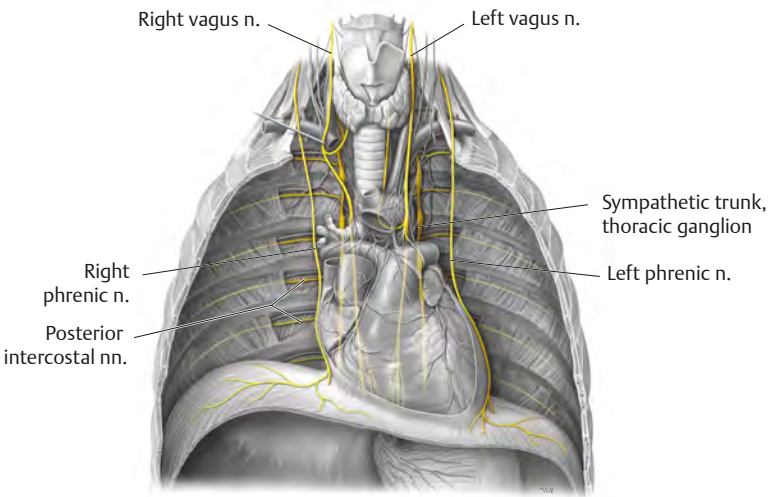
Nerves of the Thoracic Cavity

Thoracic innervation is mostly autonomic, arising from the paravertebral sympathetic trunks and parasympathetic vagus nerves. There are two exceptions: the phrenic nerves innervate the pericardium

and diaphragm (p. 66) and the intercostal nerves innervate the thoracic wall (p. 70).

Fig. 8.11 Nerves in the thorax
Anterior view of opened thorax.

A Thoracic innervation.



B Nerves of the thorax in situ. Lungs, pericardial sac, heart and costal pleura removed. *Note:* The recurrent laryngeal nerves have been slightly anteriorly retracted; normally, they occupy the groove

between the trachea and the esophagus, making them vulnerable during thyroid gland surgery.

The autonomic nervous system innervates smooth muscle, cardiac muscle, and glands. It is subdivided into the sympathetic (red) and

parasympathetic (blue) nervous systems, which together regulate blood flow, secretions, and organ function.

Fig. 8.12 Sympathetic and parasympathetic nervous systems in the thorax

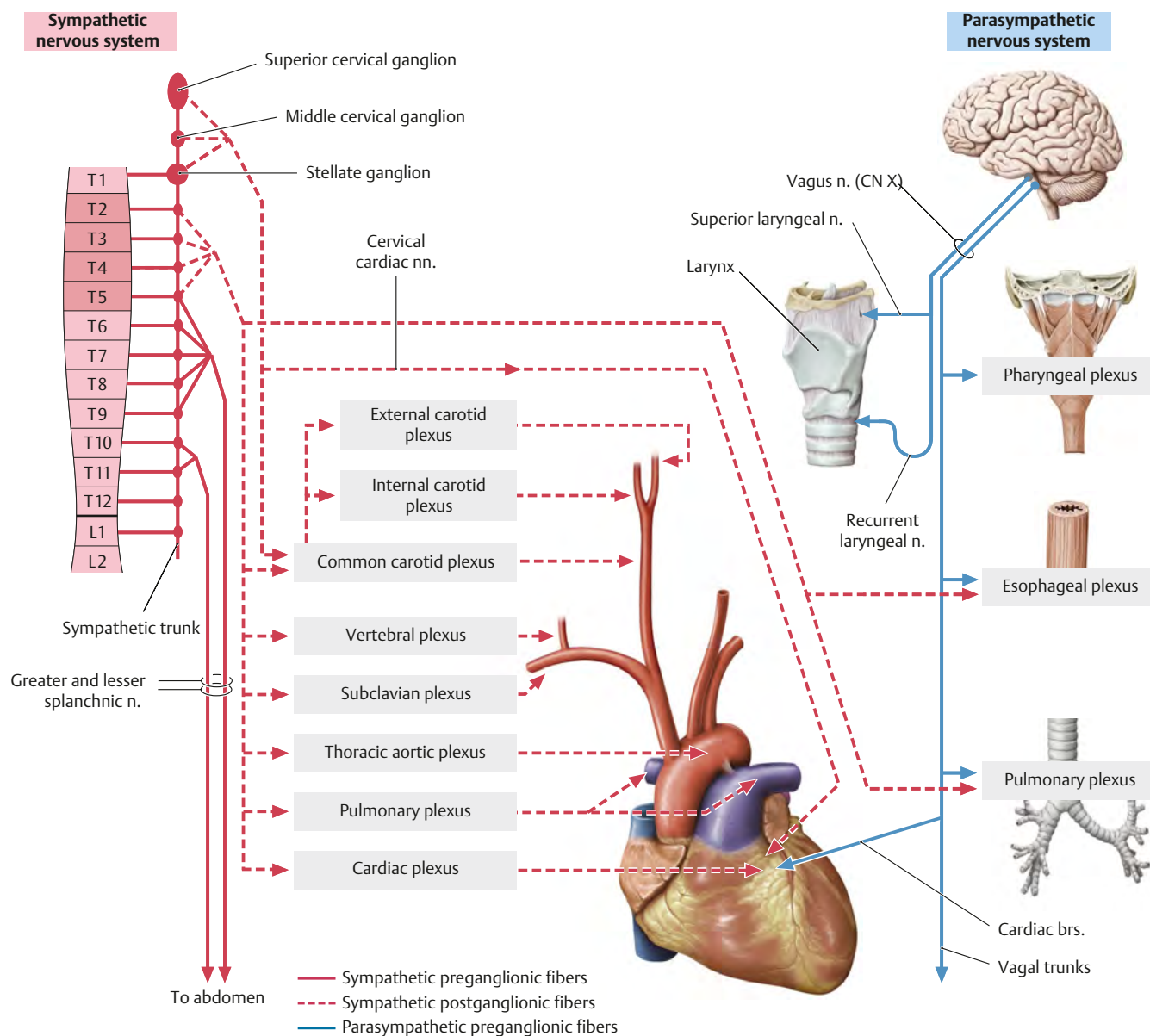


Table 8.4 Peripheral sympathetic nervous system

Origin of pre-ganglionic fibers*	Ganglion cells	Course of post-ganglionic fibers	Target
Spinal cord	Sympathetic trunk	Follow intercostal nn.	Blood vessels and glands in chest wall
		Accompany intrathoracic aa.	Visceral targets
		Gather in greater and lesser splanchnic nn.	Abdomen

*The axons of preganglionic neurons exit the spinal cord via the anterior roots and synapse with postganglionic neurons in the sympathetic ganglia.

Table 8.5 Peripheral parasympathetic nervous system

Origin of pre-ganglionic fibers	Course of preganglionic motor axons*		Target
Brainstem	Vagus n. (CN X)	Cardiac brs.	Cardiac plexus
		Esophageal brs.	Esophageal plexus
		Tracheal brs.	Trachea
		Bronchial brs.	Pulmonary plexus (bronchi, pulmonary vessels)

*The ganglion cells of the parasympathetic nervous system are scattered in microscopic groups in their target organs. The vagus n. thus carries the preganglionic motor axons to these targets.

CN = cranial n.

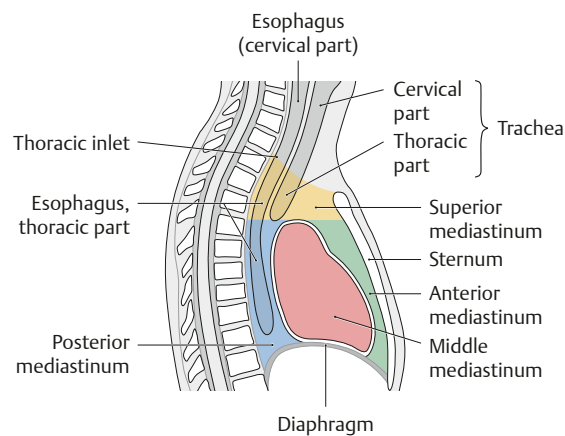
9 Mediastinum

Mediastinum: Overview

The mediastinum is the space in the thorax between the pleural sacs of the lungs. It is divided into two parts: superior and inferior. The inferior

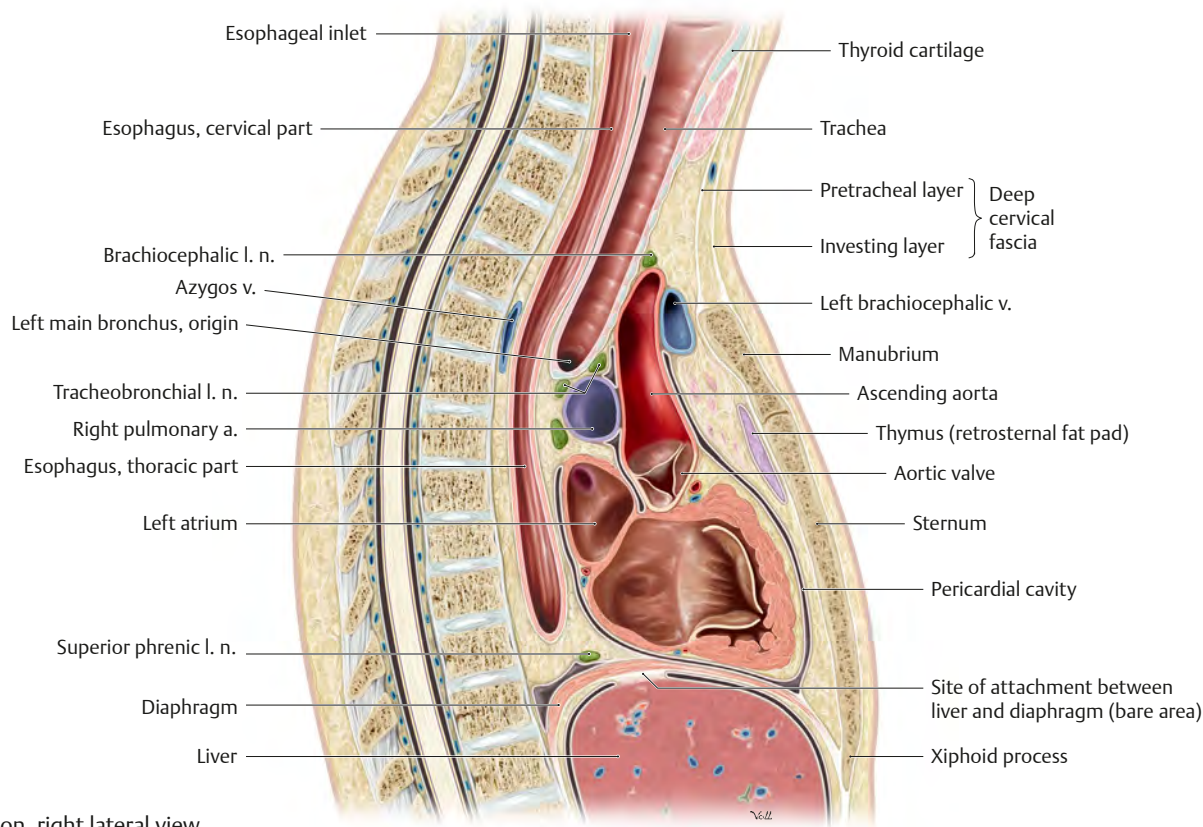
mediastinum is further divided into anterior, middle, and posterior portions.

Fig. 9.1 Divisions of the mediastinum

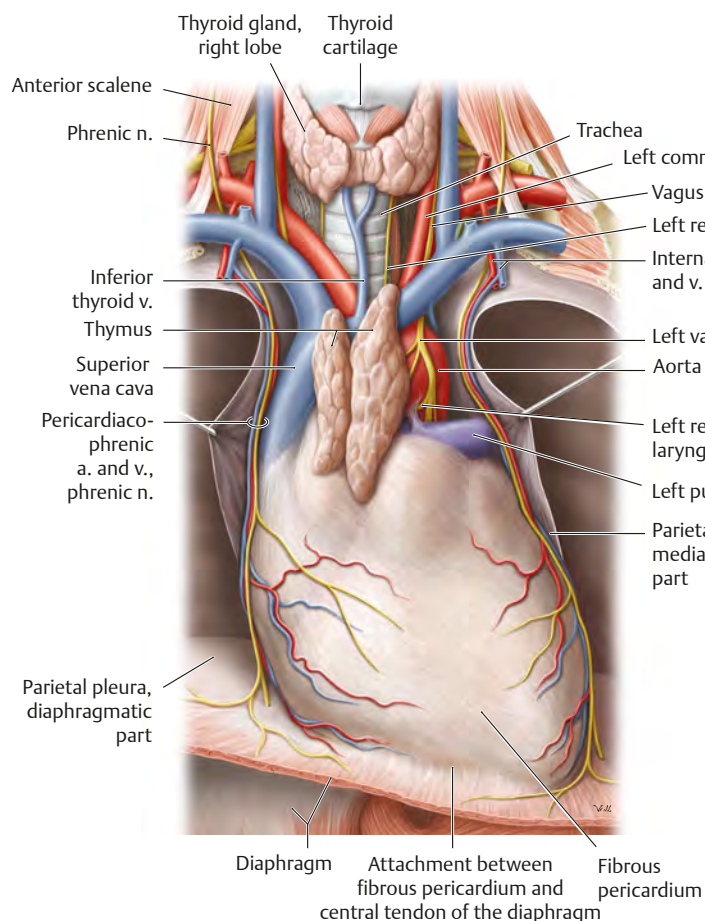


A Schematic.

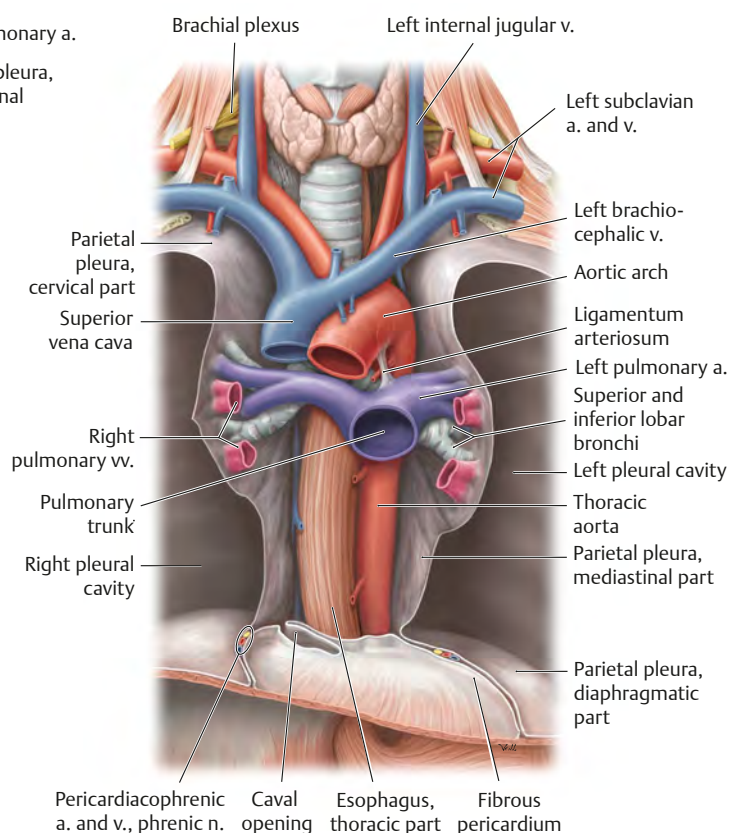
Table 9.1 Contents of the mediastinum				
	Superior mediastinum	Inferior mediastinum		
		Anterior	Middle	Posterior
Organs	• Thymus • Trachea • Esophagus	• Thymus, inferior aspects (especially in children)	• Heart • Pericardium	• Esophagus
Arteries	• Aortic arch • Brachiocephalic trunk • Left common carotid a. • Left subclavian a.	• Smaller vessels	• Ascending aorta • Pulmonary trunk and brs. • Pericardiophrenic aa.	• Thoracic aorta and brs.
Veins and lymph vessels	• Superior vena cava • Brachiocephalic vv. • Thoracic duct and right lymphatic duct	• Smaller vessels, lymphatics, and l.n.	• Superior vena cava • Azygos v. • Pulmonary vv. • Pericardiophrenic vv.	• Azygos v. • Accessory hemiazygos and hemiazygos vv. • Thoracic duct
Nerves	• Vagus nn. • Left recurrent laryngeal n. • Cardiac nn. • Phrenic nn.	• None	• Phrenic nn.	• Vagus nn.



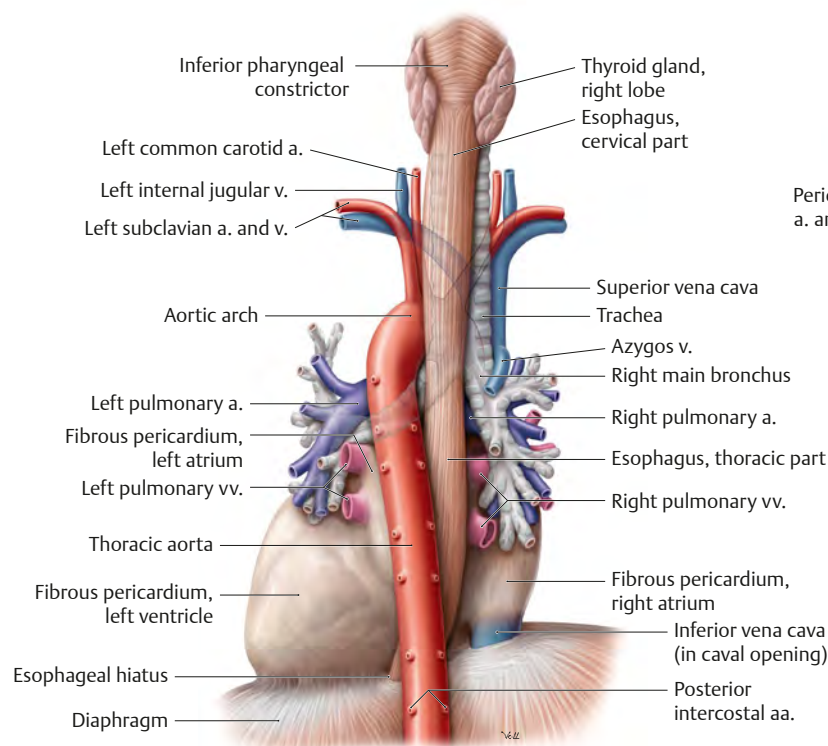
B Midsagittal section, right lateral view.

Fig. 9.2 Contents of the mediastinum

A Anterior view. The thymus extends into the anterior division of the inferior mediastinum and grows throughout childhood. At puberty, high levels of circulating sex hormones cause the thymus to atrophy leaving indistinguishable pieces embedded in the fat that now occupies the anterior mediastinum.

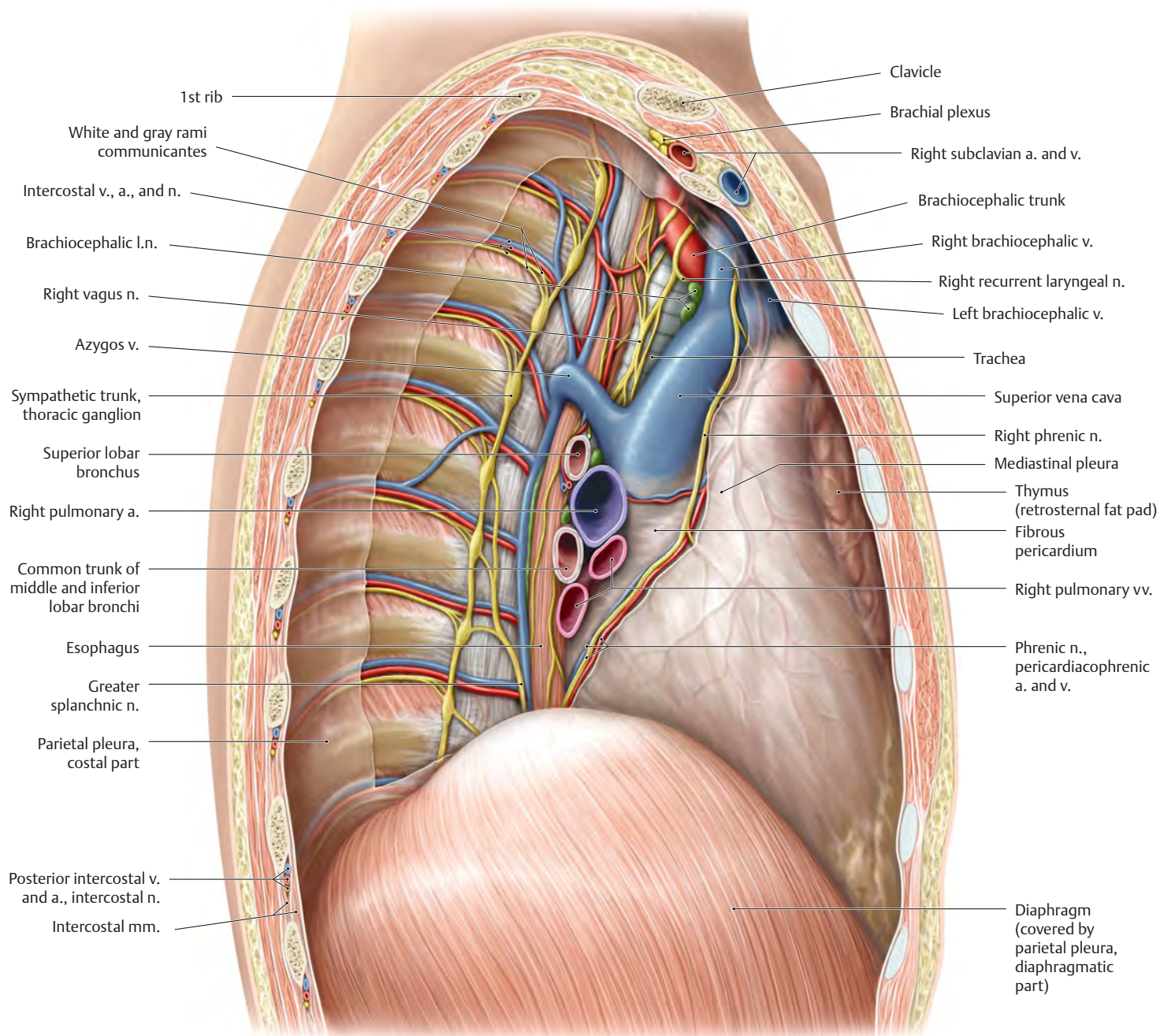


B Anterior view with lungs, heart, pericardium, and thymus removed.

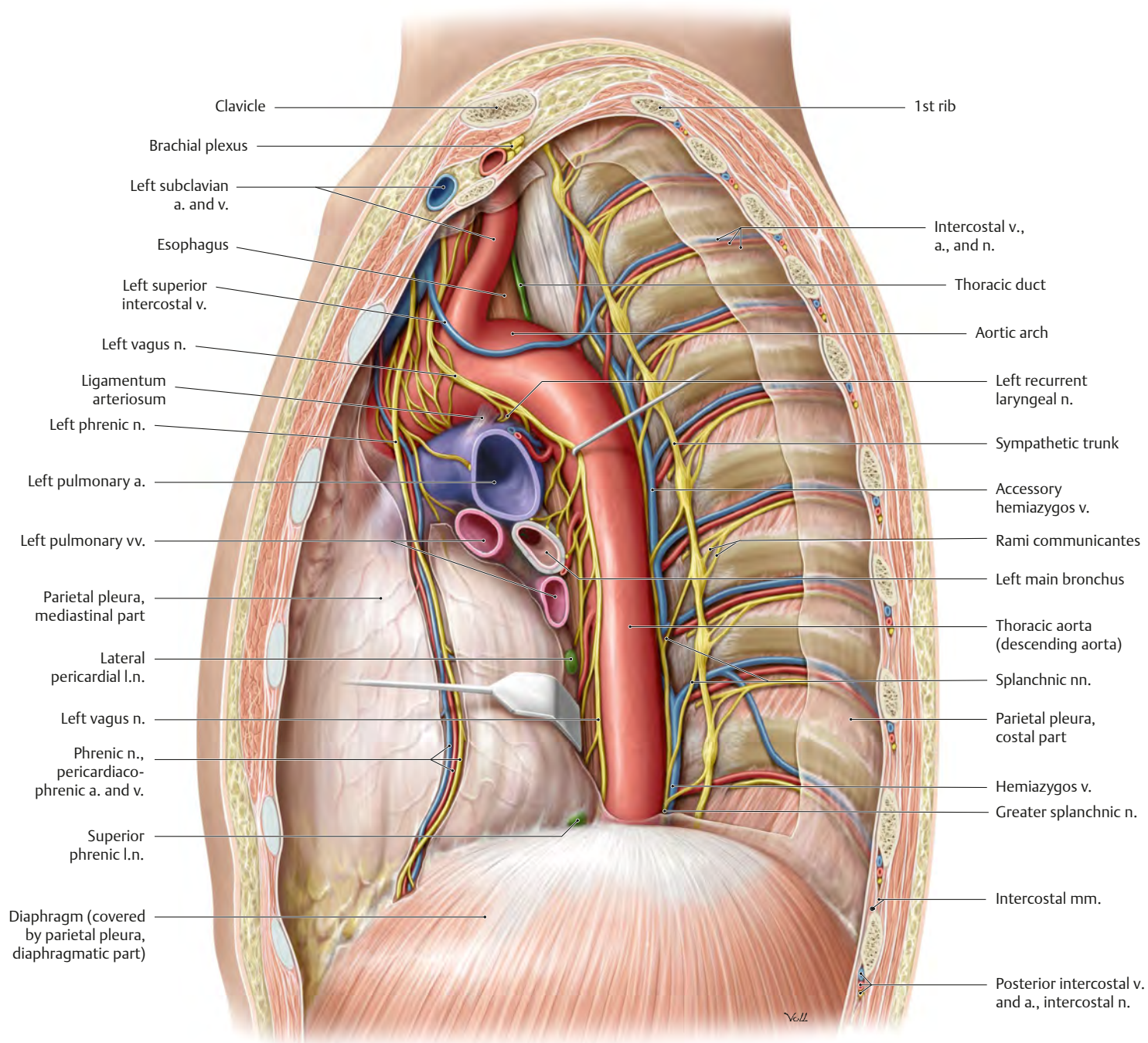


C Posterior view.

Fig. 9.3 Mediastinum



A Right lateral view, parasagittal section. Note the many structures passing between the superior and inferior (middle and posterior) mediastinum.



B Left lateral view, parasagittal section. *Removed:* Left lung and parietal pleura. *Revealed:* Posterior mediastinal structures.

Heart: Functions & Relations

The heart pumps the blood: unoxygenated blood to the lungs and oxygenated blood throughout the body. It is located posterior to the sternum in the middle portion of the mediastinum in the pericardial

cavity, located between the right and left pleural cavities containing the lungs. The apex of the cone-shaped heart points anteriorly and to the left in the thoracic cavity.

Fig. 9.4 Circulation
Oxygenated blood is shown in red; deoxygenated blood in blue. See p. 104 for prenatal circulation.

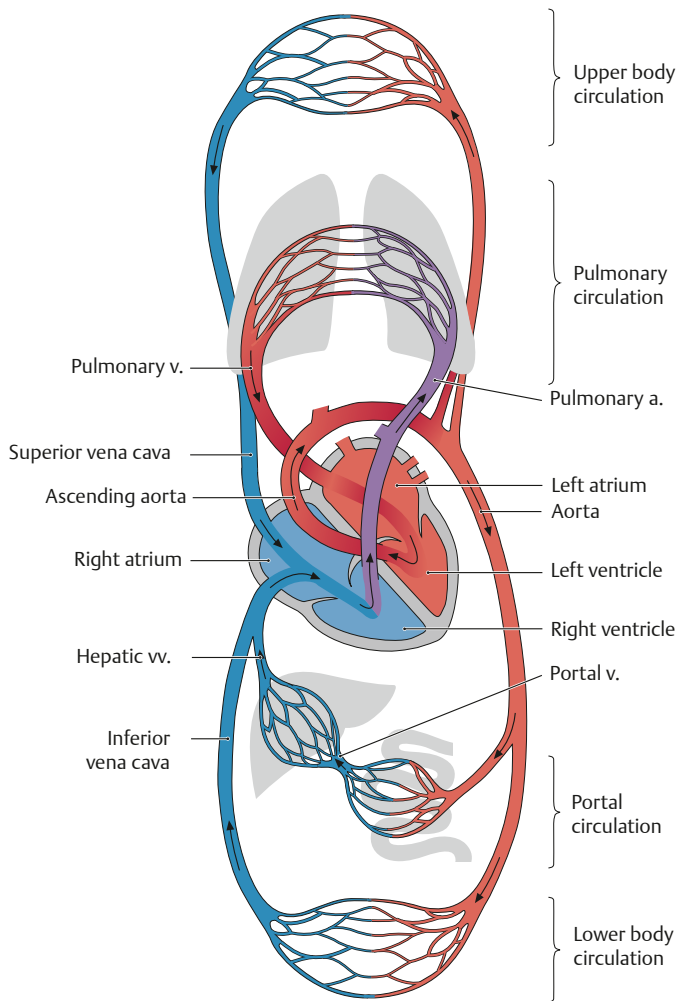
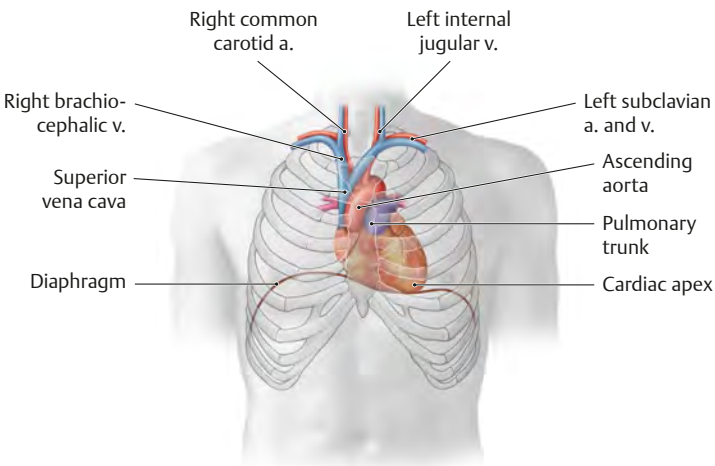
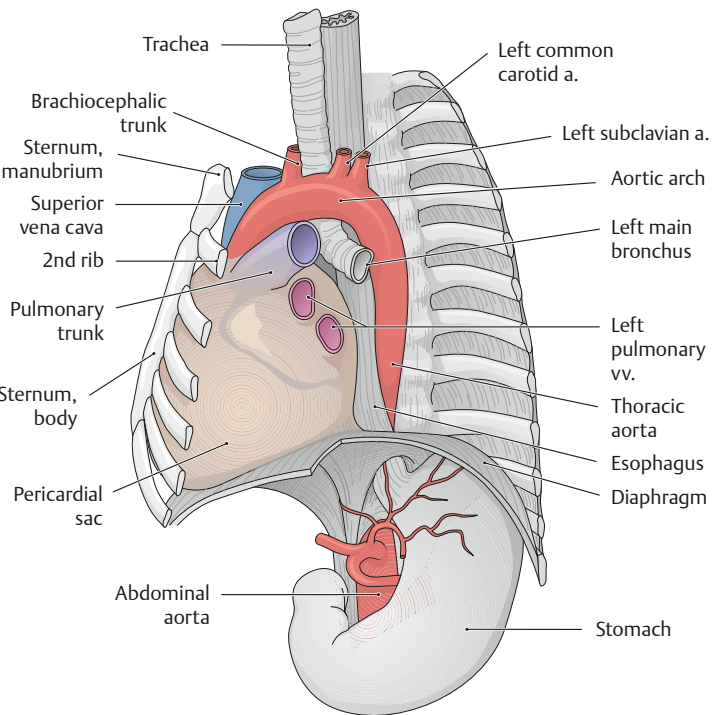


Fig. 9.5 Topographical relations of the heart



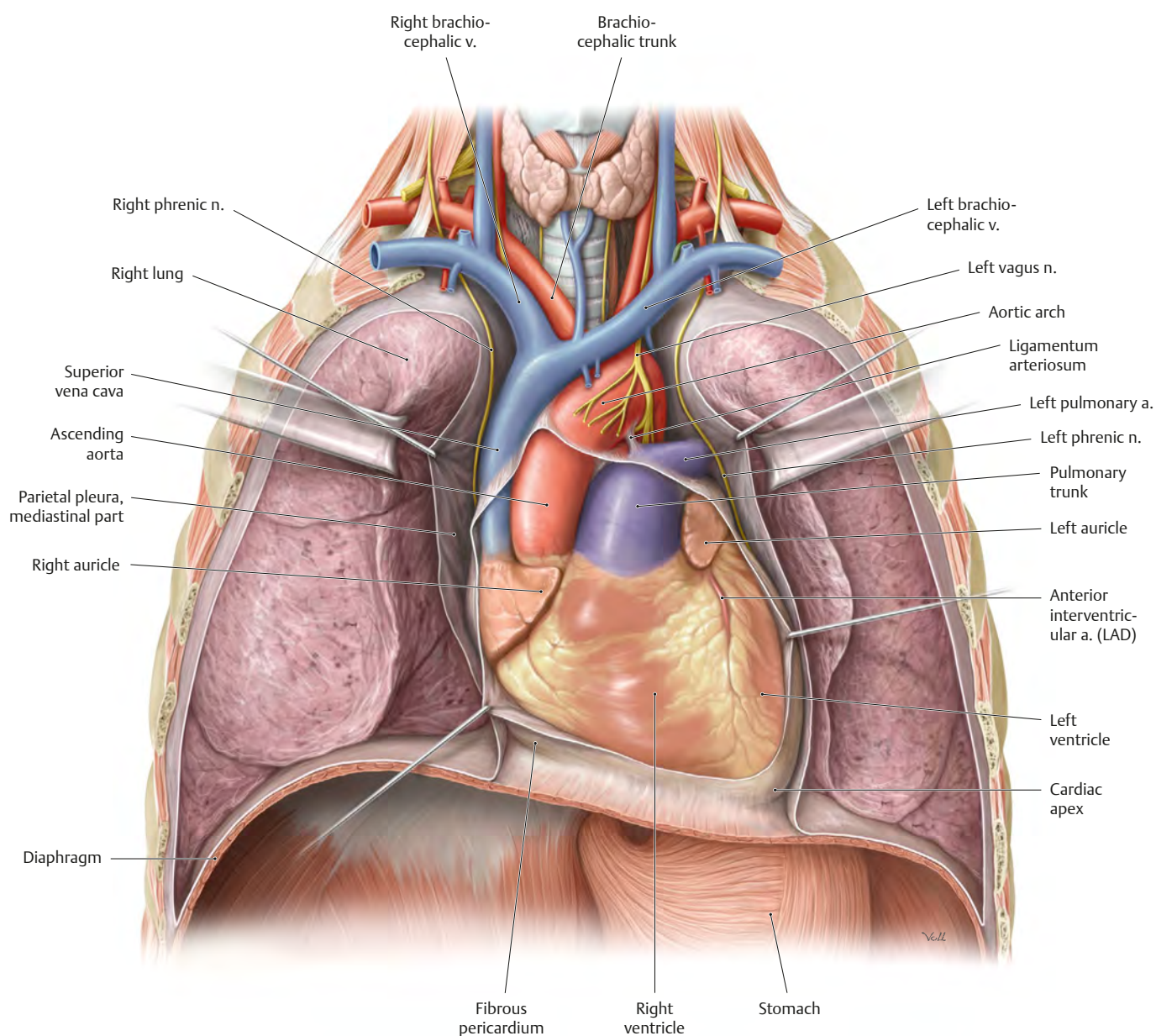
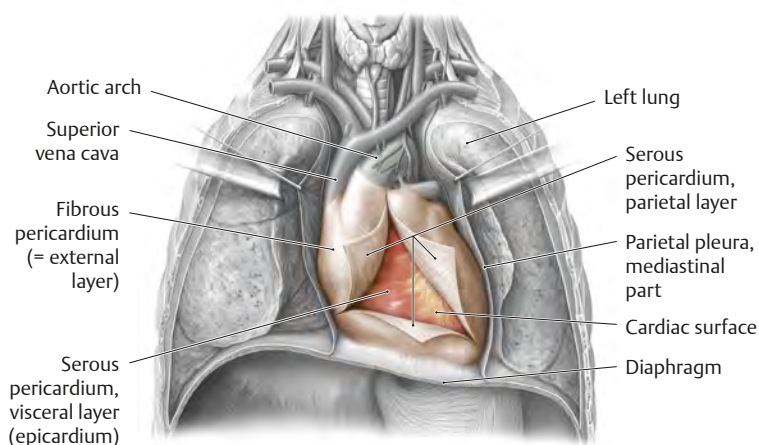
A Projection of the heart and great vessels onto chest, anterior view.



B Left lateral view. *Removed:* Left thoracic wall and left lung.

Fig. 9.6 Heart in situ

A Anterior view of the opened thorax with the thymus removed and flaps of the anterior layer of the pericardial sac reflected to reveal the heart.



B Anterior view of the opened thorax with thymus and anterior pericardium removed to reveal the heart.

Fig. 9.7 Posterior pericardial cavity

Anterior view of opened thorax with the anterior pericardium removed. The heart has been partially elevated to reveal the posterior pericardial cavity and the oblique pericardial sinus.

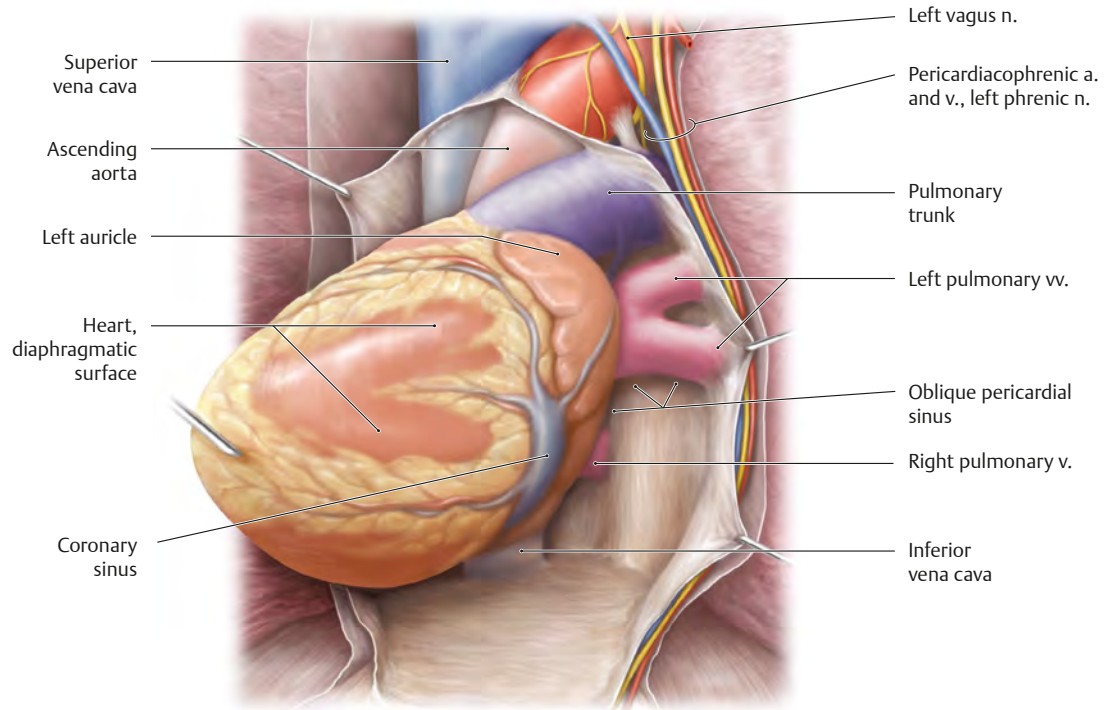


Fig. 9.8 Posterior pericardium

Anterior view of the opened thorax with the anterior pericardium and heart removed to reveal the posterior pericardium and the oblique pericardial sinus. The transverse pericardial sinus is the passage between the reflections of the serous layer of the pericardium around the arterial and venous great vessels of the heart.

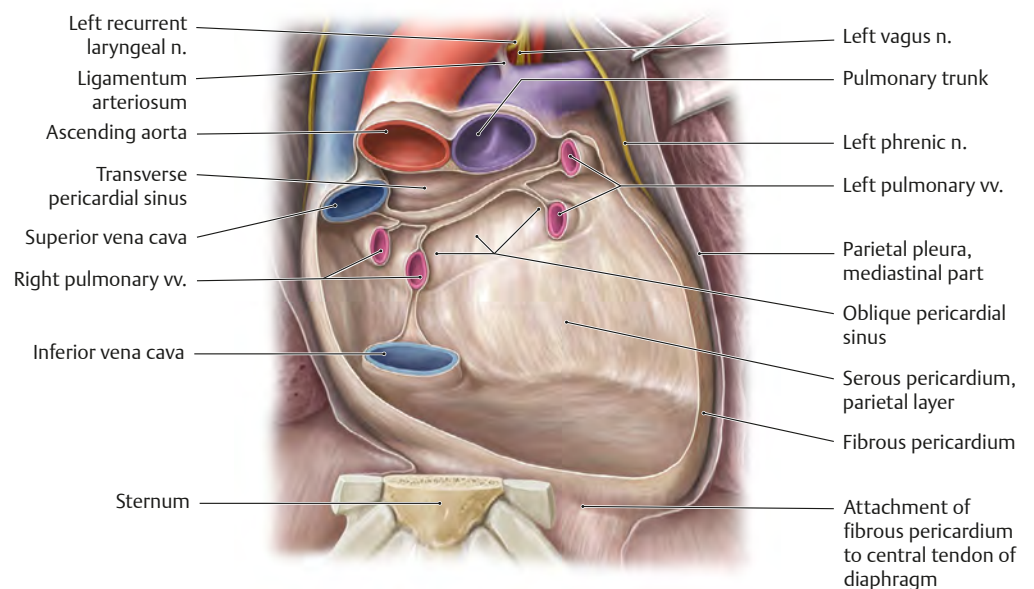
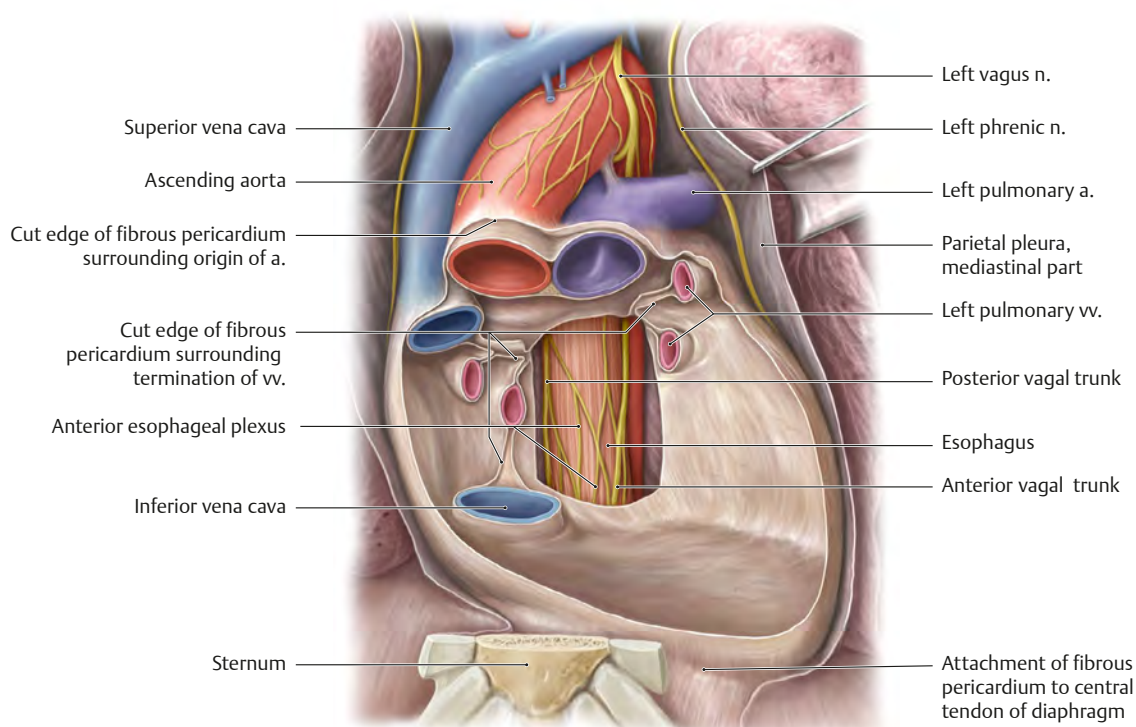
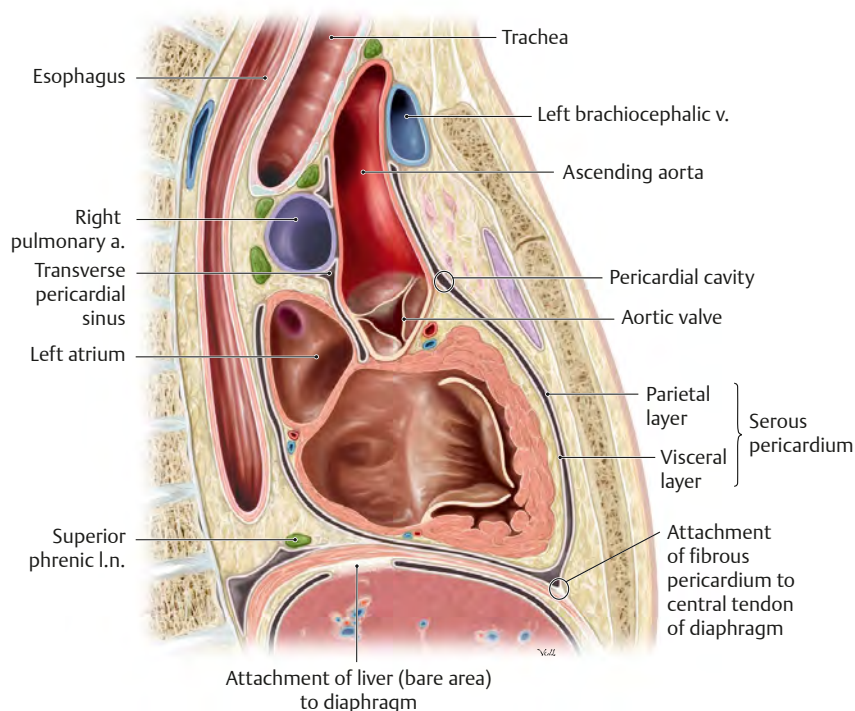


Fig. 9.9 Posterior relations of the heart

Anterior view of the opened thorax with the anterior pericardium and heart removed and a window cut in the posterior pericardium to reveal the structures immediately posterior to the heart. This shows the close relationship of the esophagus to the heart, which is used in the transesophageal sonogram to assess the left atrium of the heart.

**Fig. 9.10 Pericardium, pericardial cavity, and transverse pericardial sinus**

Sagittal section through the mediastinum. The fibrous pericardium is attached to the central tendon of the diaphragm and is continuous superiorly with the outer layer of the great vessels. The parietal layer of serous pericardium lines the inner surface of the fibrous pericardium and the visceral layer adheres to the heart. The pericardial cavity, the space between the parietal and visceral layers of serous pericardium around the heart, is filled with a thin layer of serous fluid that allows for frictionless movement. Where the parietal and visceral layers of serous pericardium reach and reflect around the great vessels, they are continuous with one another. The passage between the arterial and venous reflections of the serous pericardium is the transverse pericardial sinus.

**Clinical box 9.1****Cardiac Tamponade**

Rapid increases of fluid or blood within the pericardial sac inhibits full expansion of the heart, reducing cardiac blood return, thus decreasing cardiac output. This condition, cardiac tamponade (compression), is potentially fatal, unless relieved. The fluid or blood must first be removed to restore cardiac function and then the cause of the fluid or blood accumulation corrected.

Heart: Surfaces & Chambers

Note the reflection of visceral serous pericardium to become parietal serous pericardium.

Fig. 9.11 Surfaces of the heart
The heart has three surfaces: anterior (sternocostal), posterior (base), and inferior (diaphragmatic).

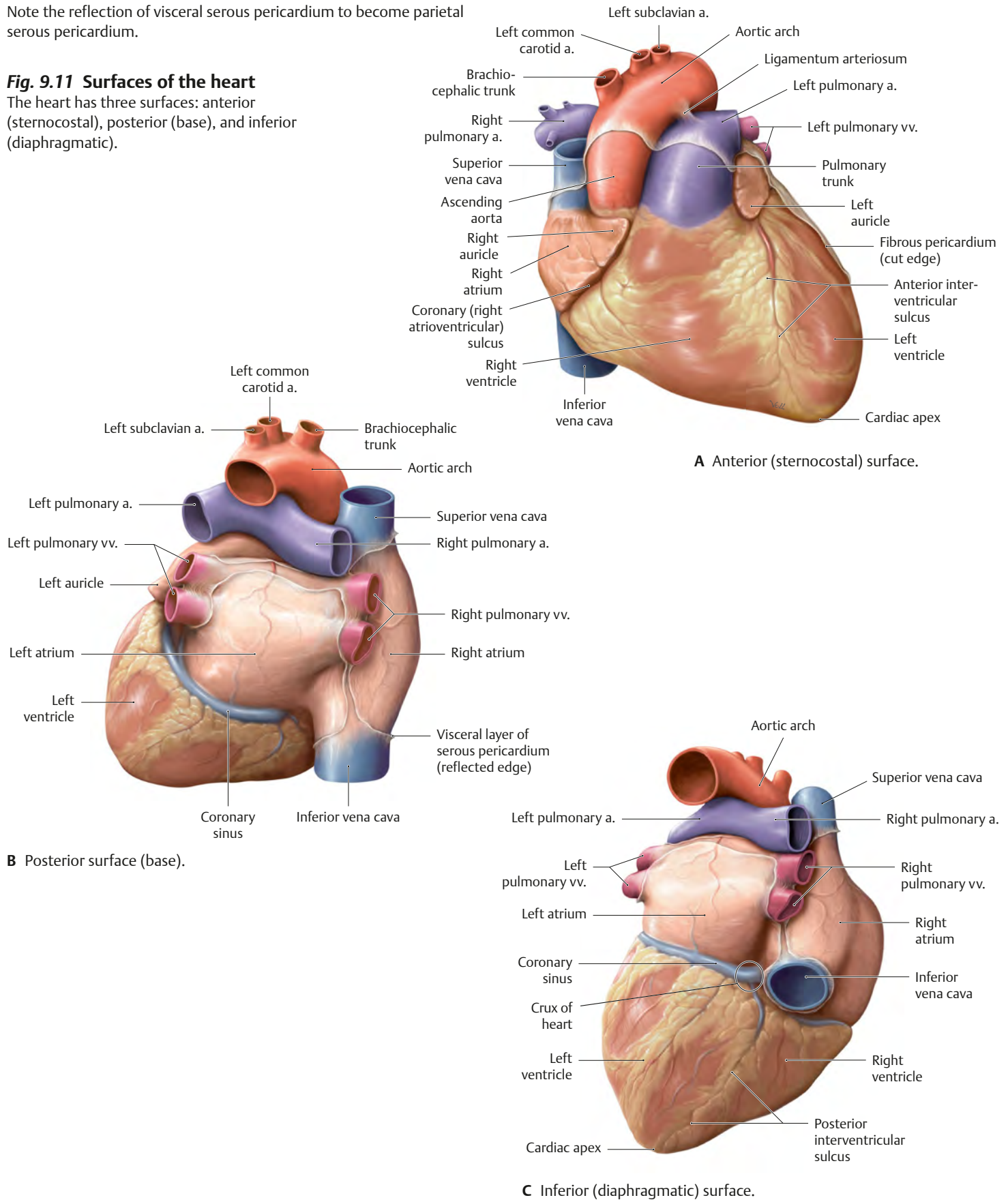
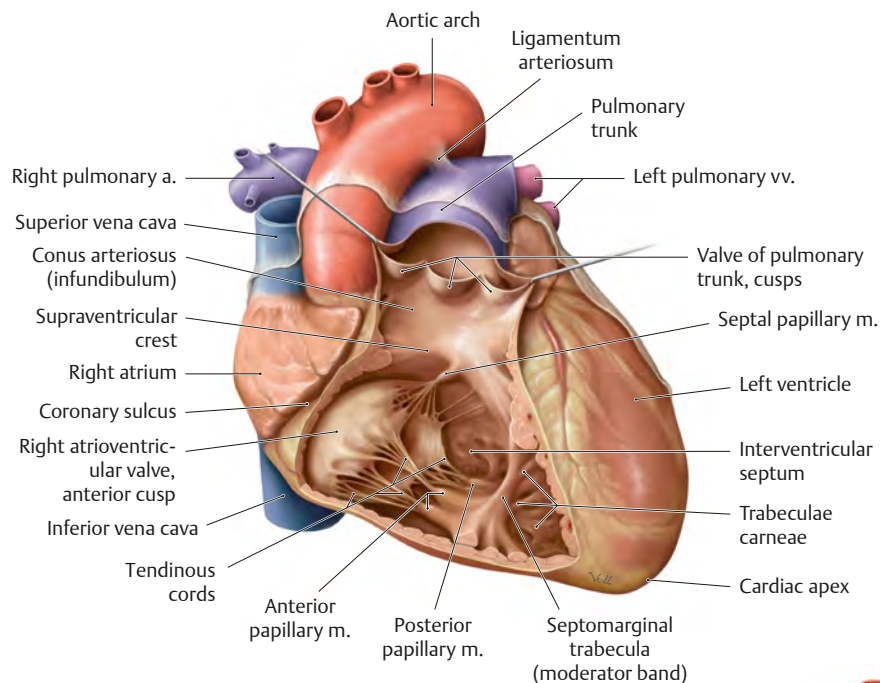
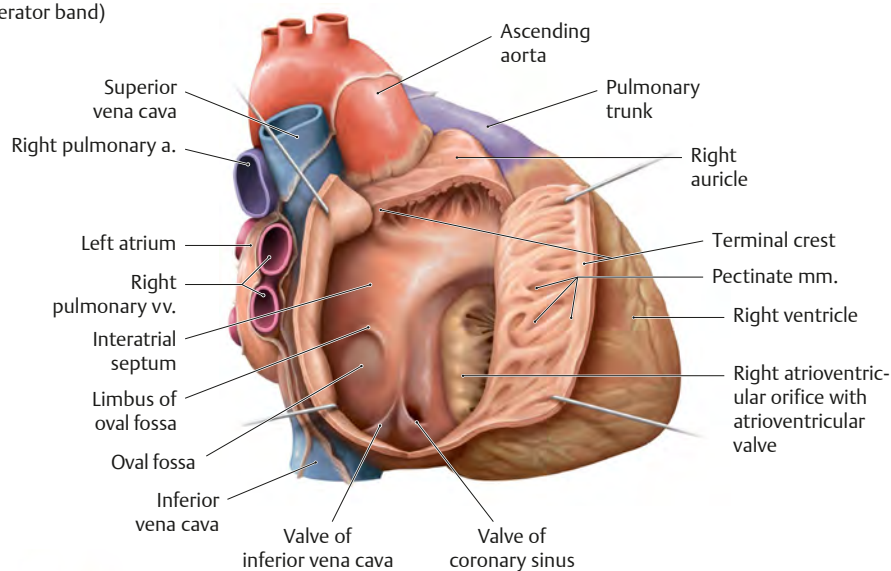


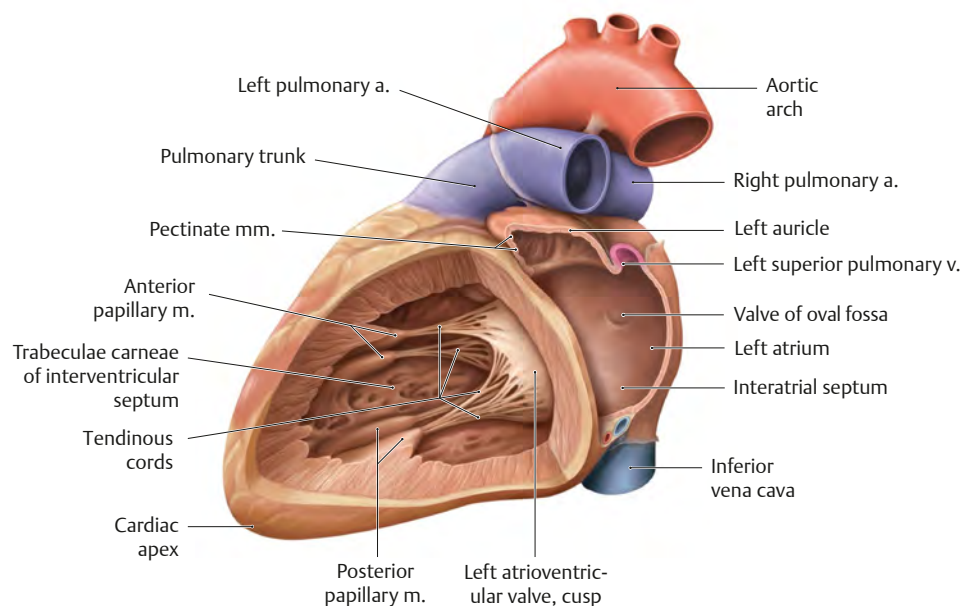
Fig. 9.12 Chambers of the heart



A Right ventricle, anterior view. Note the supraventricular crest, which marks the adult boundary between the embryonic ventricle and the bulbus cordis (now conus arteriosus).



B Right atrium, right lateral view.



C Left atrium and ventricle, left lateral view. Note the irregular trabeculae carneae characteristic of the ventricular wall.

Heart: Valves

The cardiac valves are divided into two types: semilunar and atrio-ventricular. The two semilunar valves (aortic and pulmonary) located at the base of the two great arteries of the heart regulate passage of

blood from the ventricles to the aorta and pulmonary trunk. The two atrioventricular valves (left and right) lie at the interface between the atria and ventricles.

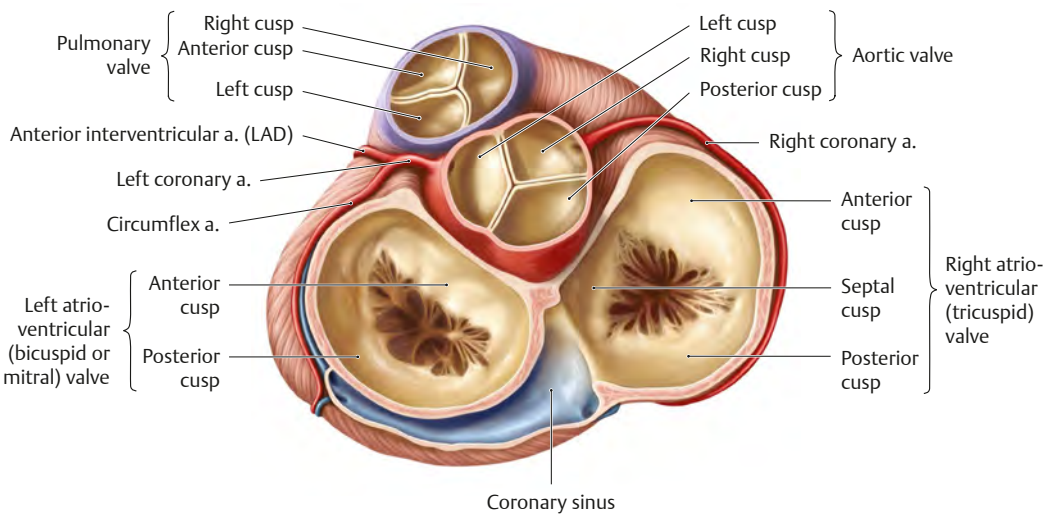
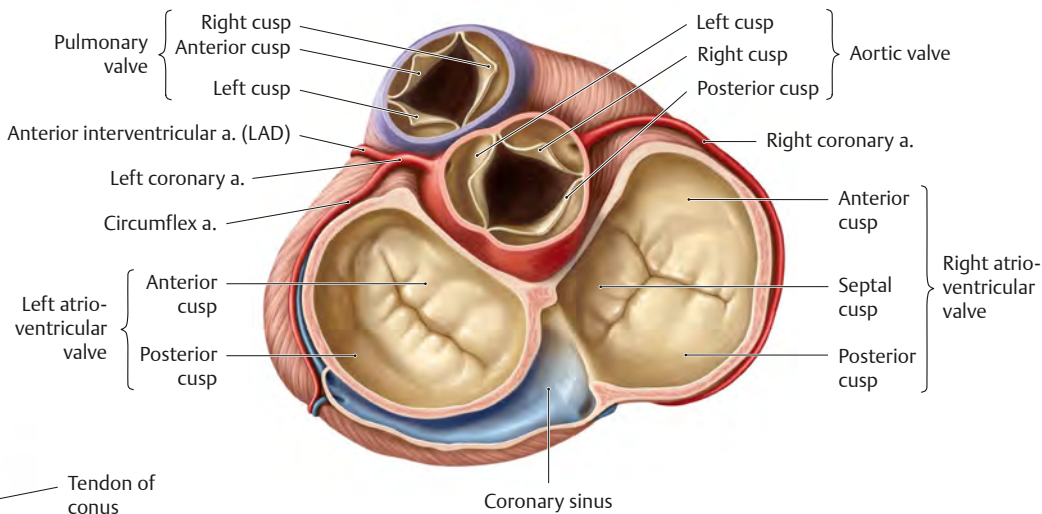
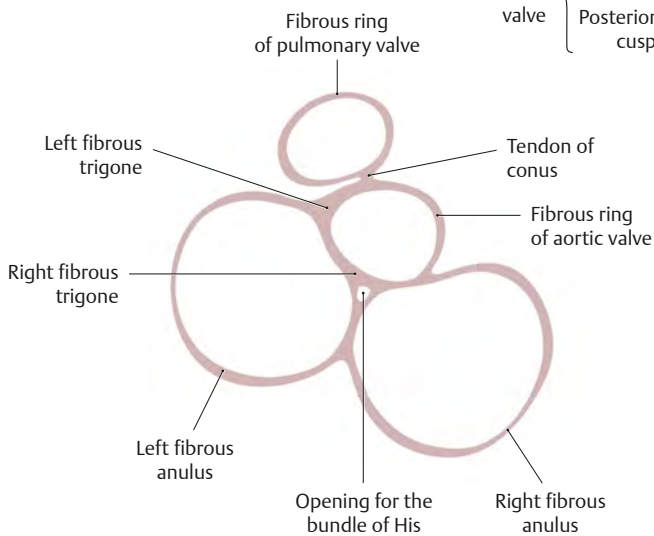


Fig. 9.13 Cardiac valves
Plane of cardiac valves, superior view.
Removed: Atria and great arteries.

A Ventricular diastole (relaxation of the ventricles). *Closed:* Semilunar valves. *Open:* Atrioventricular valves.



B Ventricular systole (contraction of the ventricles). *Closed:* Atrioventricular valves. *Open:* Semilunar valves.

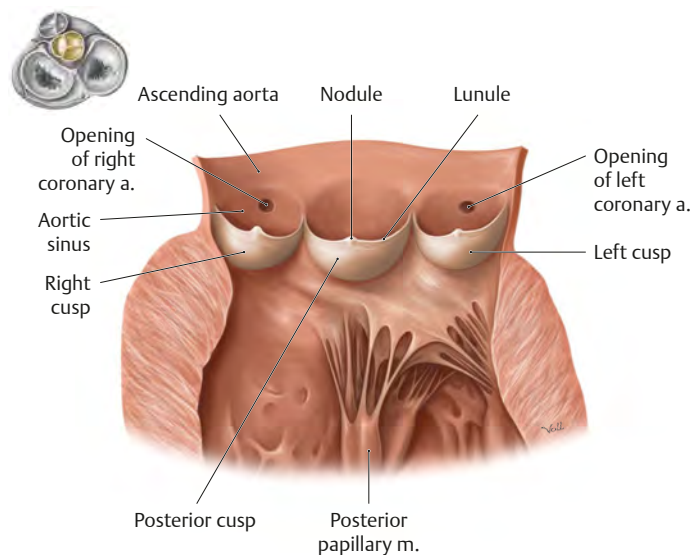


C Cardiac skeleton, superior view. The cardiac skeleton is formed by dense fibrous connective tissue. The fibrous anuli (rings) and intervening trigones separate the atria from the ventricles. This provides mechanical stability, electrical insulation (see **p. 102** for cardiac conduction system), and an attachment point for the cardiac muscles and valve cusps.

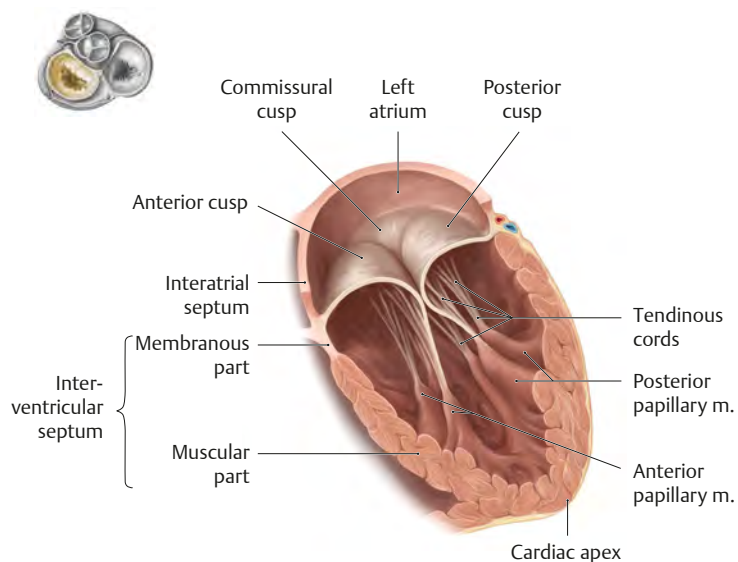
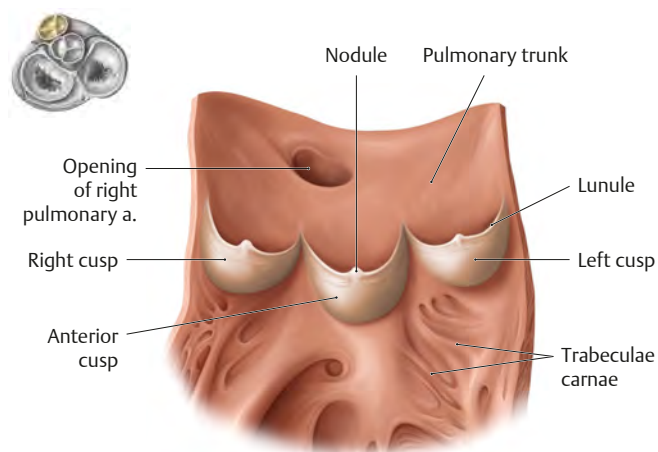
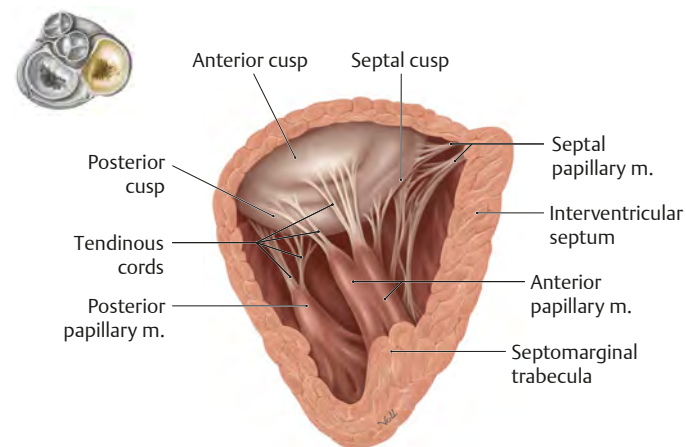
Table 9.2 Position and auscultation sites of cardiac valves		
Valve	Anatomical projection	Auscultation site
Aortic valve	Left sternal border (at level of 3rd rib)	Right 2nd intercostal space (at sternal margin)
Pulmonary valve	Left sternal border (at level of 3rd costal cartilage)	Left 2nd intercostal space (at sternal margin)
Left atrioventricular valve	Left 4th/5th costal cartilage	Left 5th intercostal space (at midclavicular line) or cardiac apex
Right atrioventricular valve	Sternum (at level of 5th costal cartilage)	Left 5th intercostal space (at sternal margin)

Fig. 9.14 Semilunar valves

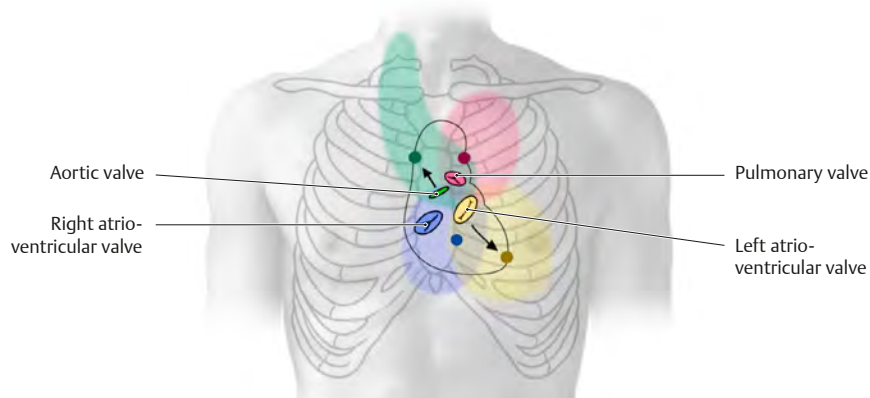
Valves have been longitudinally sectioned and opened.

**A Aortic valve.****Fig. 9.15 Atrioventricular valves**

Anterior view during ventricular systole.

**A Left atrioventricular valve.****B Pulmonary valve.****B Right atrioventricular valve.****Clinical box 9.2****Auscultation of the cardiac valves**

Heart sounds, produced by closure of the semilunar and atrioventricular valves, are carried by the blood flowing through the valve. The resulting sounds are therefore best heard "downstream," at defined auscultation sites (dark circles on diagram). Valvular heart disease causes turbulent blood flow through the valve; this produces a murmur that may be detected in the region of auscultation.



Arteries & Veins of the Heart

Fig. 9.16 Coronary arteries and cardiac veins

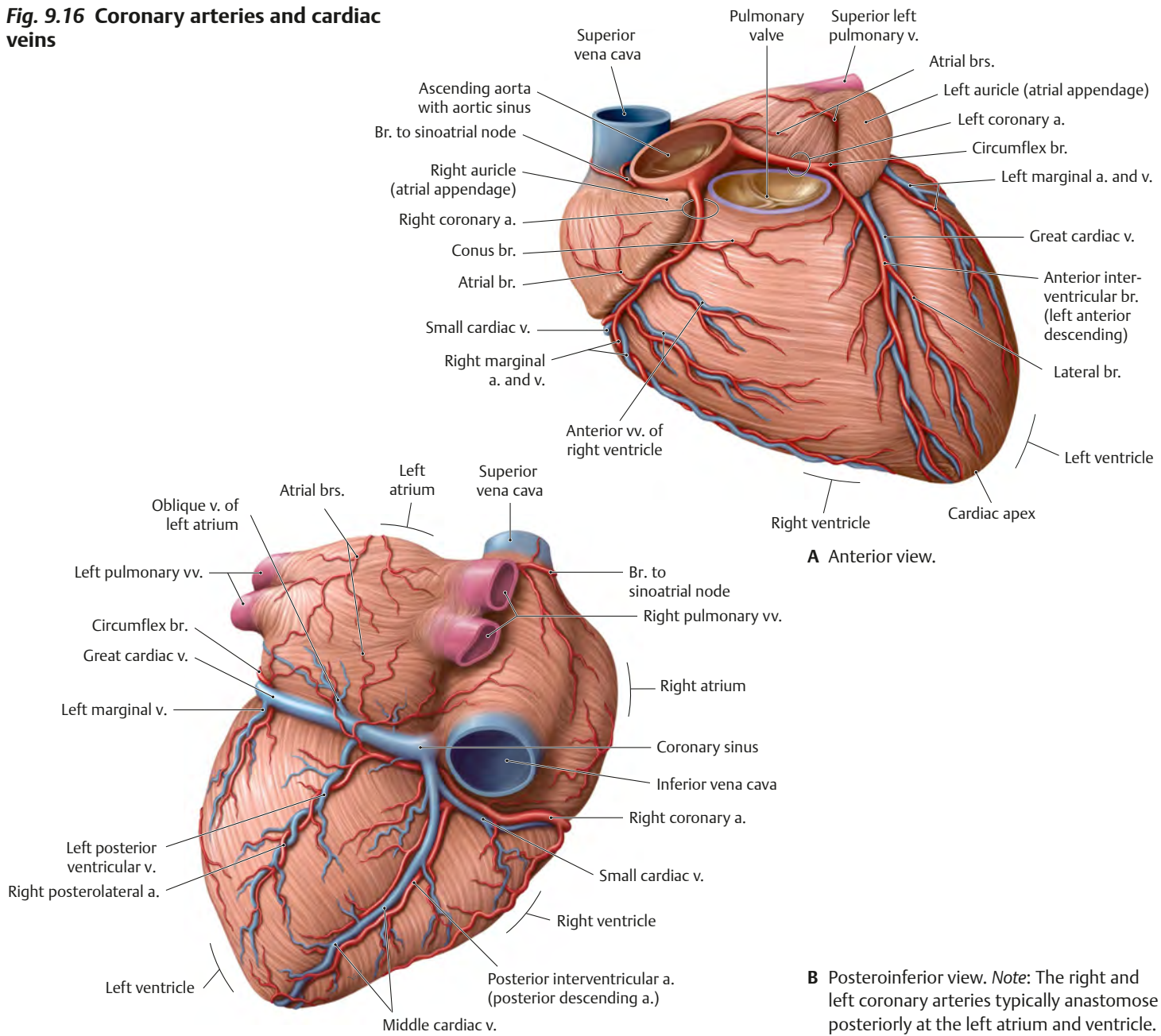
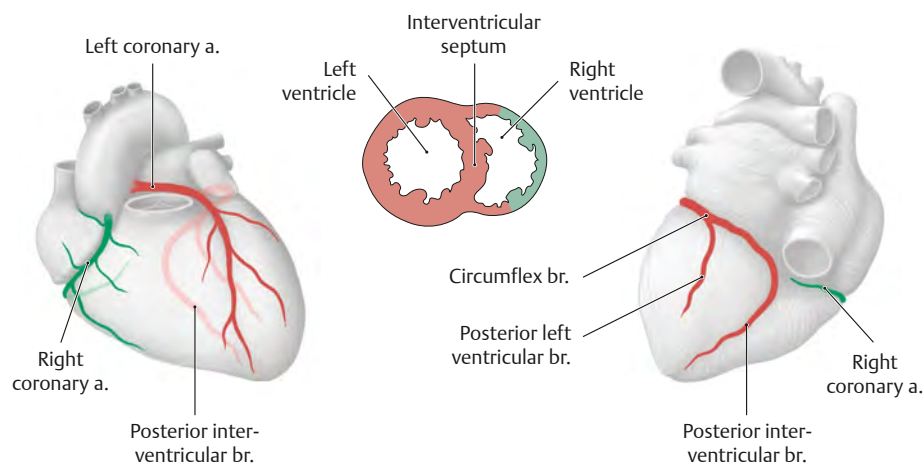


Table 9.3 Branches of the coronary arteries	
Left coronary artery	Right coronary artery
Circumflex br. • Atrial br. • Left marginal a. • Posterior left ventricular br.	Br. to SA node
	Conus br.
	Atrial br.
	Right marginal a.
Anterior interventricular br. (left anterior descending) • Conus br. • Lateral br. • Interventricular septal brs.	Posterior interventricular br. (posterior descending) • Interventricular septal brs.
	Br. to AV node
	Right posterolateral a.
AV, atrioventricular; SA, sinoatrial.	

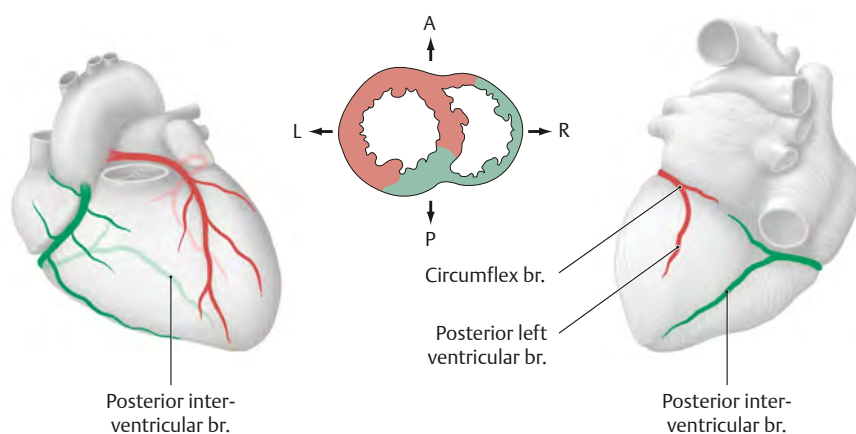
Table 9.4 Divisions of the cardiac veins		
Vein	Tributaries	Drainage to
Anterior cardiac vv. (not shown)		Right atrium
Great cardiac v.	Anterior interventricular v.	Coronary sinus
	Left marginal v.	
	Oblique v. of left atrium	
Left posterior ventricular v.		
Middle cardiac v. (posterior interventricular v.)		
Small cardiac v.	Anterior vv. of right ventricle	
	Right marginal v.	

Fig. 9.17 Distribution of the coronary arteries

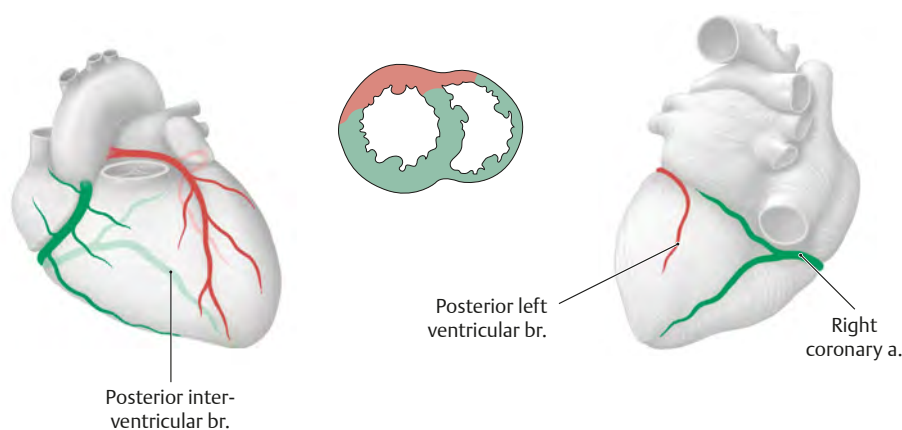
Anterior and posterior views of the heart, with superior views of transverse sections through the ventricles. The “distribution” of the coronary arteries refers to the area of the myocardium supplied by each artery, as seen in the transverse views, but the term “dominance” refers to the artery that gives rise to the posterior interventricular artery, as seen in the anterior and posterior views. Right coronary artery and branches (green); left coronary artery and branches (red).



A Left coronary dominance (15–17%).



B Balanced distribution, right coronary artery dominance (67–70%).



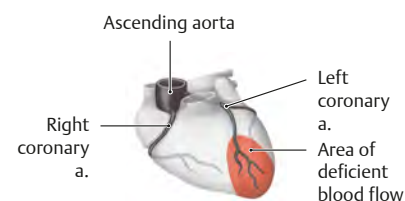
C Right coronary dominance (~15%).

**Clinical box 9.3****Disturbed coronary blood flow**

Although the coronary arteries are connected by structural anastomoses, they are end arteries from a functional standpoint. The most frequent cause of deficient blood flow is *atherosclerosis*, a narrowing of the coronary lumen due to plaque-like deposits on the vessel wall. When the decrease in luminal size (stenosis) reaches a critical point, coronary blood flow is restricted, causing chest pain (*angina pectoris*). Initially, this pain is induced by physical effort, but eventually it persists at rest, often radiating to characteristic sites (e.g., medial side of left upper limb, left side of head and neck). A myocardial infarction occurs when deficient blood supply causes myocardial tissue to die (necrosis). The location and extent of the infarction depends on the stenosed vessel (see **A–E**, after Heinecker).



A Supra-apical anterior infarction.



B Apical anterior infarction.



C Anterior lateral infarction.



D Posterior lateral infarction.



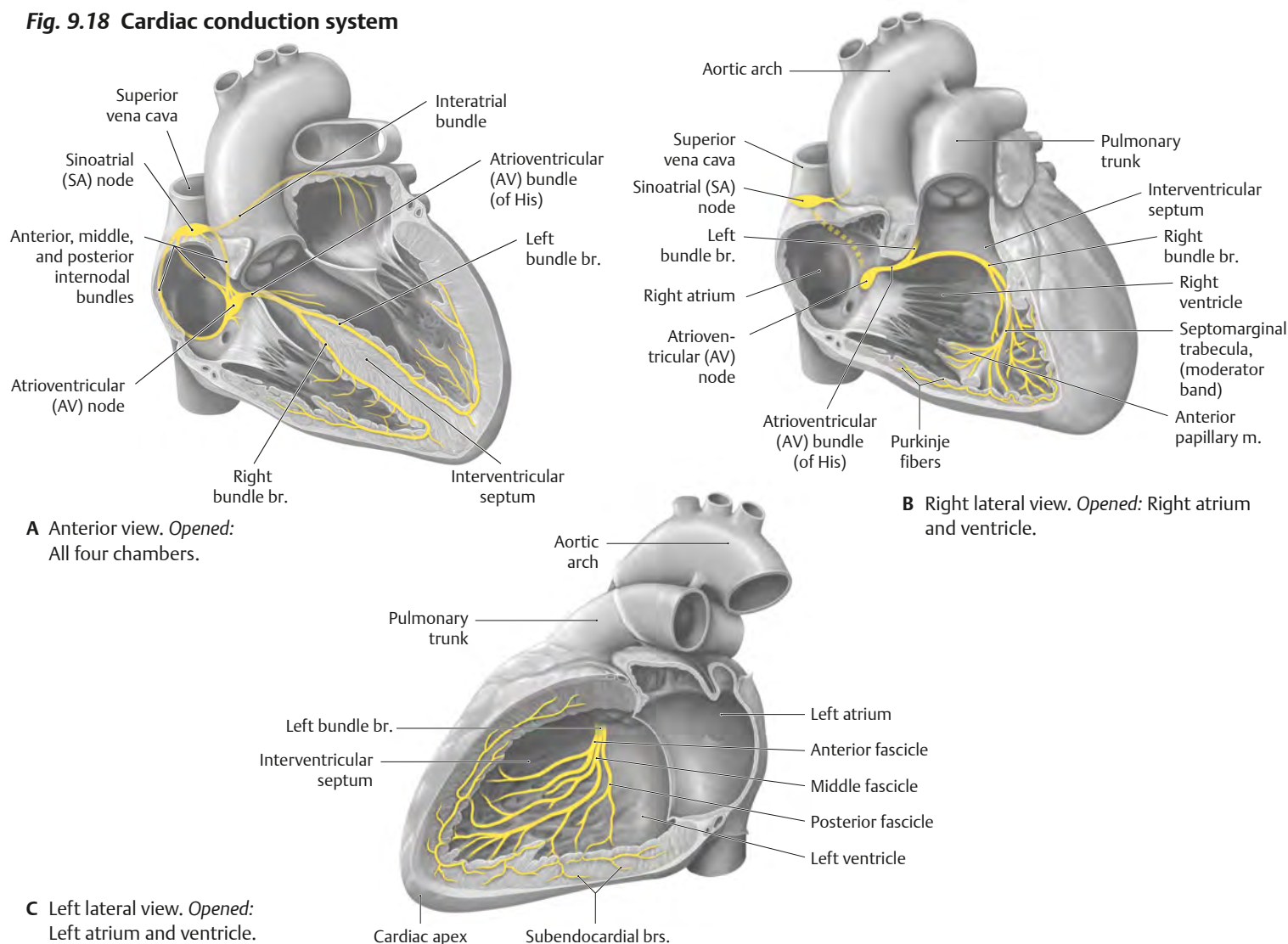
E Posterior infarction.

Conduction & Innervation of the Heart

Contraction of cardiac muscle is modulated by the cardiac conduction system. This system of specialized myocardial cells (Purkinje fibers) generates and conducts excitatory impulses in the heart. The conduc-

tion system contains two nodes, both located in the right atrium: the sinoatrial (SA) node, known as the pacemaker, and the atrioventricular (AV) node.

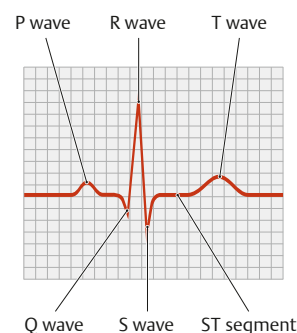
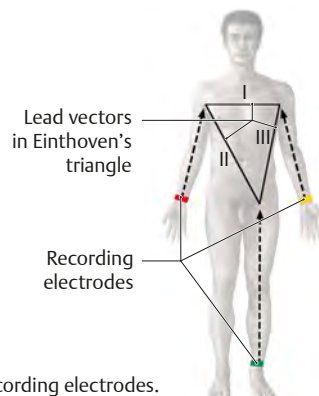
Fig. 9.18 Cardiac conduction system



Clinical box 9.4

Electrocardiogram (ECG)

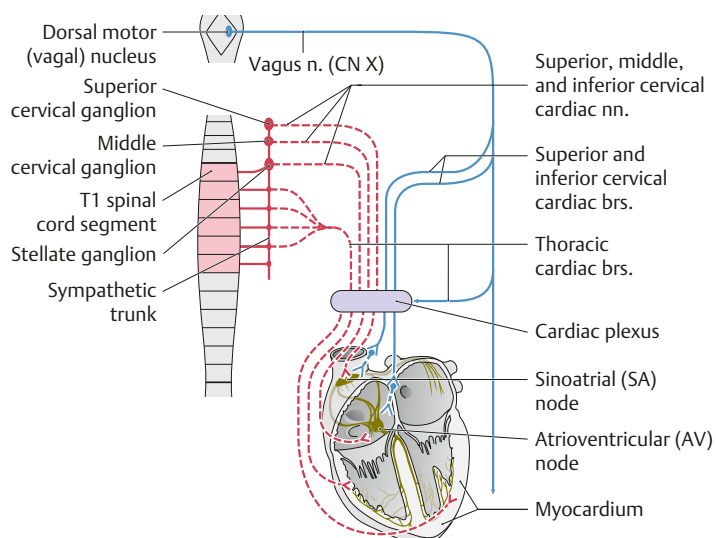
The cardiac impulse (a physical dipole) travels across the heart and may be detected with electrodes. The use of three electrodes that separately record electrical activity of the heart along three axes or vectors (Einthoven limb leads) generates an electrocardiogram (ECG). The ECG graphs the cardiac cycle ("heartbeat"), reducing it to a series of waves, segments, and intervals. These ECG components can be used to determine whether cardiac impulses are normal or abnormal (e.g., myocardial infarction, chamber enlargement). *Note:* Although only three leads are required, a standard ECG examination includes at least two others (Goldberger, Wilson leads).



Sympathetic innervation: Preganglionic neurons from T1 to T6 spinal cord segments send fibers to synapse on postganglionic neurons in the cervical and upper thoracic sympathetic ganglia. The three cervical cardiac nerves and thoracic cardiac branches contribute to the cardiac

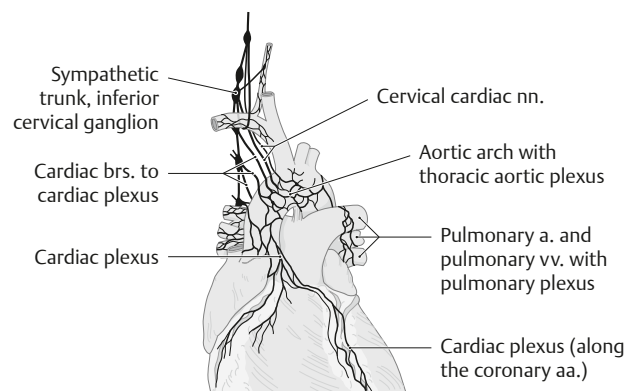
plexus. Parasympathetic innervation: Preganglionic neurons and fibers reach the heart via cardiac branches, some of which also arise in the cervical region. They synapse on postganglionic neurons near the SA node and along the coronary arteries.

Fig. 9.19 Autonomic innervation of the heart

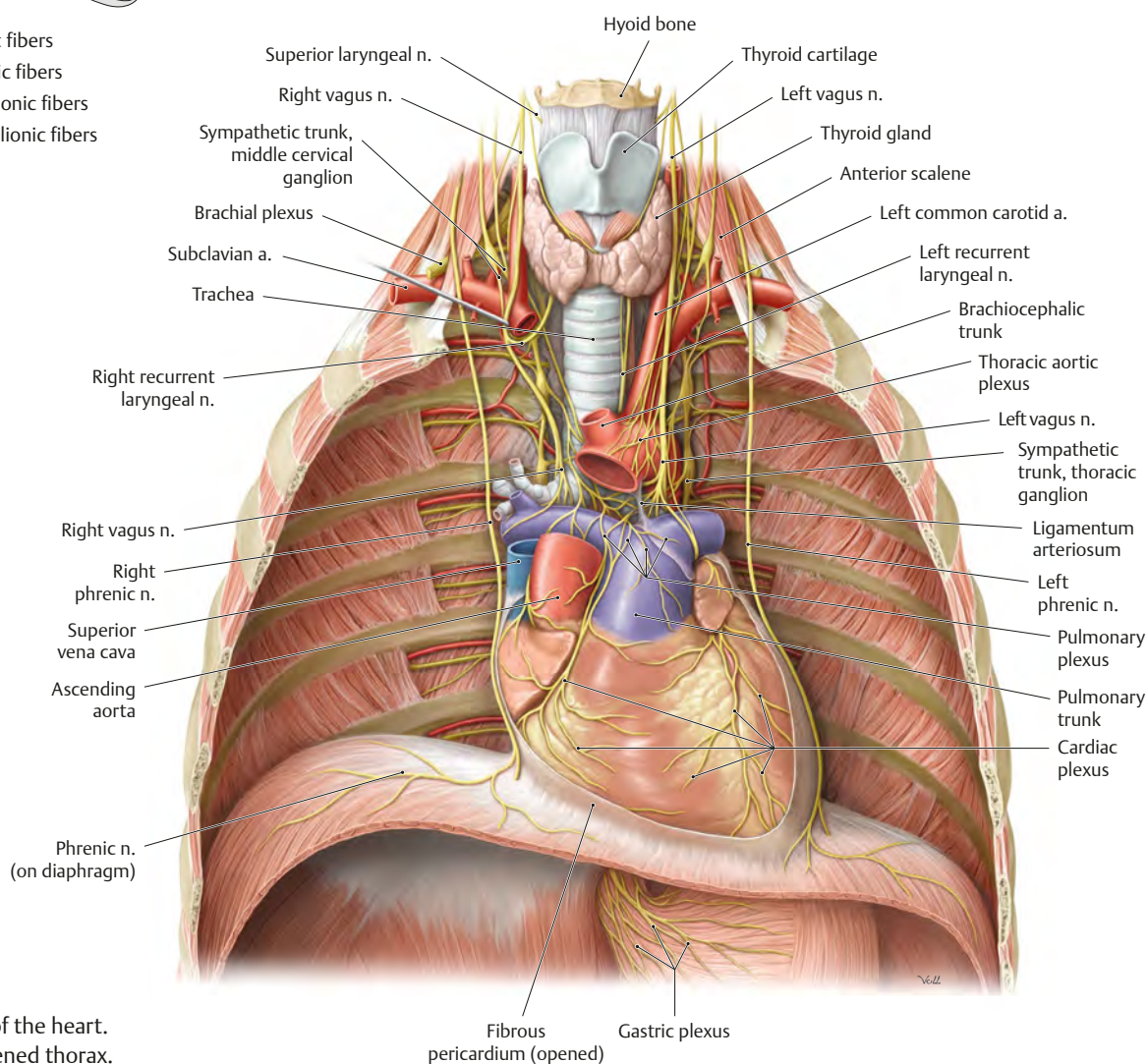


- Sympathetic preganglionic fibers
- - - Sympathetic postganglionic fibers
- Parasympathetic preganglionic fibers
- - - Parasympathetic postganglionic fibers

A Schematic.



B Autonomic plexuses of the heart, right lateral view. Note the continuity between the cardiac, aortic, and pulmonary plexuses.



C Autonomic nerves of the heart. Anterior view of opened thorax.

Fig. 9.20 Prenatal circulation

After Fritsch and Kühnel.

- ① Oxygenated and nutrient-rich fetal blood from the placenta passes to the fetus via the umbilical vein.
- ② Approximately half of this blood bypasses the liver (via the ductus venosus) and enters the inferior vena cava. The remainder enters the portal vein to supply the liver with nutrients and oxygen.
- ③ Blood entering the right atrium from the inferior vena cava bypasses the right ventricle (as the lungs are not yet functioning) to enter the left atrium via the oval foramen, a right-to-left shunt.
- ④ Blood from the superior vena cava enters the right atrium, passes to the right ventricle, and moves into the pulmonary trunk. Most of this blood enters the aorta via the ductus arteriosus, a right-to-left shunt.
- ⑤ The partially oxygenated blood in the aorta returns to the placenta via the paired umbilical arteries that arise from the internal iliac arteries.

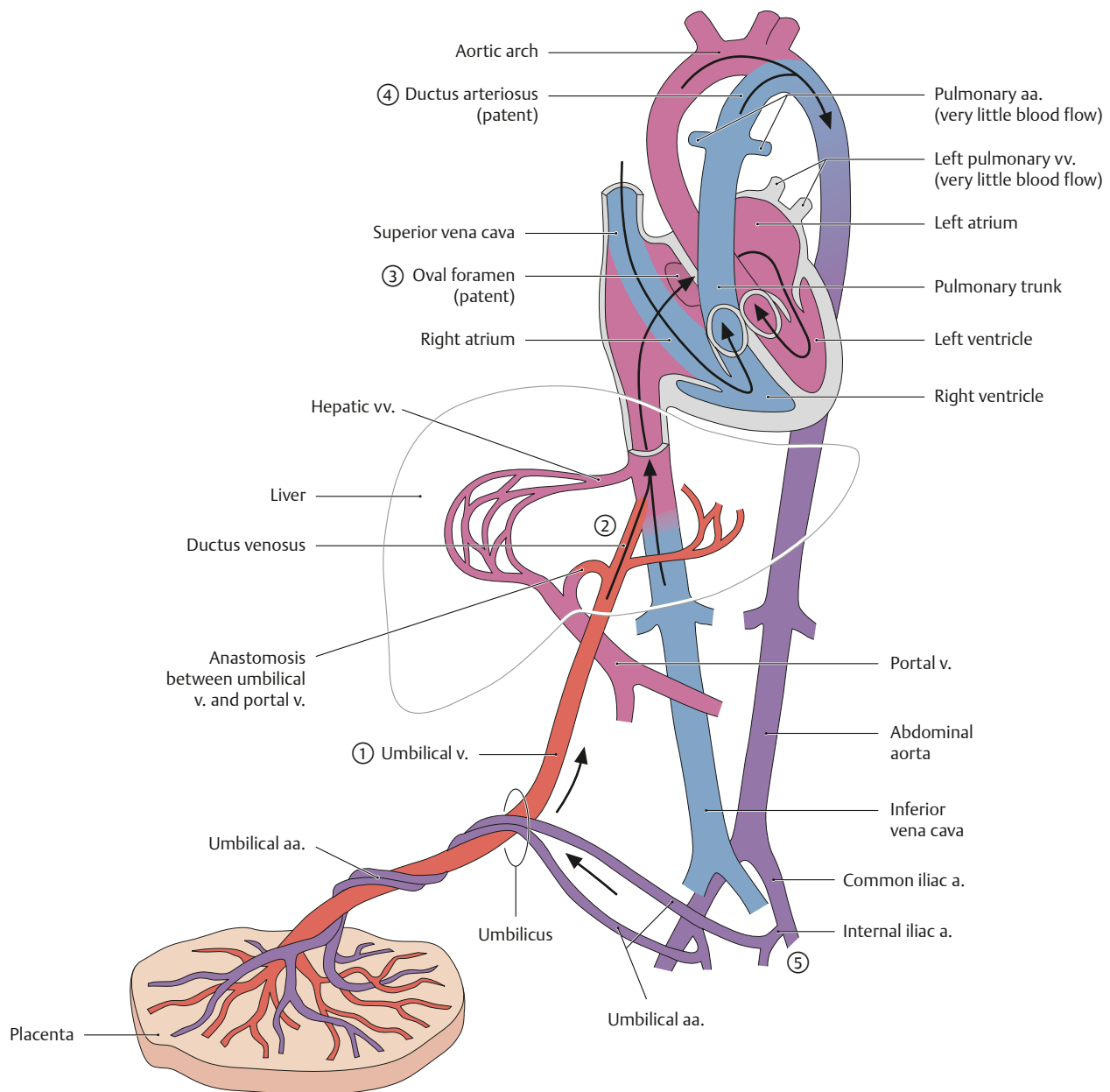


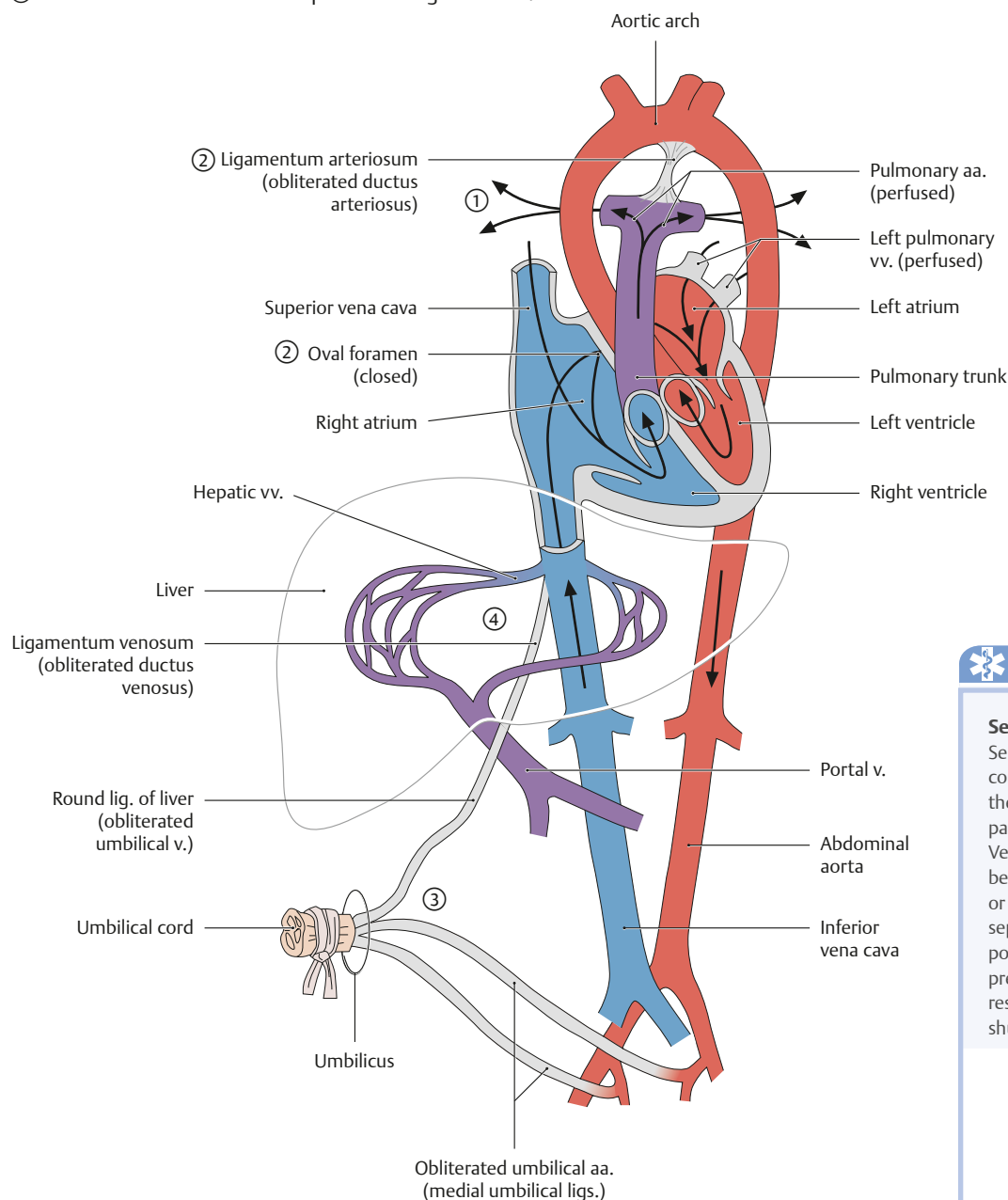
Fig. 9.21 Postnatal circulation

After Fritsch and Kühnel.

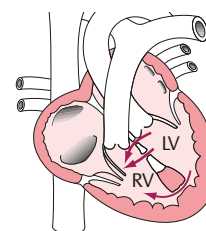
- ① As pulmonary respiration begins at birth, pulmonary blood pressure falls, causing blood from the right pulmonary trunk to enter the pulmonary arteries.
- ② The foramen ovale and ductus arteriosus close, eliminating the fetal right-to-left shunts. The pulmonary and systemic circulations in the heart are now separate.
- ③ As the infant is separated from the placenta, the umbilical arteries occlude (except for the proximal portions), along with the umbilical vein and ductus venosus.
- ④ Blood to be metabolized now passes through the liver.

Table 9.5**Derivatives of fetal circulatory structures**

Fetal structure	Adult remnant
Ductus arteriosus	Ligamentum arteriosum
Foramen ovale	Oval fossa (fossa ovalis)
Ductus venosus	Ligamentum venosum
Umbilical v.	Round lig. of the liver (ligamentum teres)
Umbilical a.	Medial umbilical lig.

**Clinical box 9.5****Septal defects**

Septal defects, the most common type of congenital heart defect, allow blood from the left chambers of the heart to improperly pass into the right chambers during systole. Ventricular septal defect (VSD, shown below) is a defect in either the membranous or muscular portion of the ventricular septum—most commonly the membranous portion. Patent foramen ovale, the most prevalent form of *atrial* septal defect (ASD), results from improper closure of the fetal shunt. LV, left ventricle; RV, right ventricle.

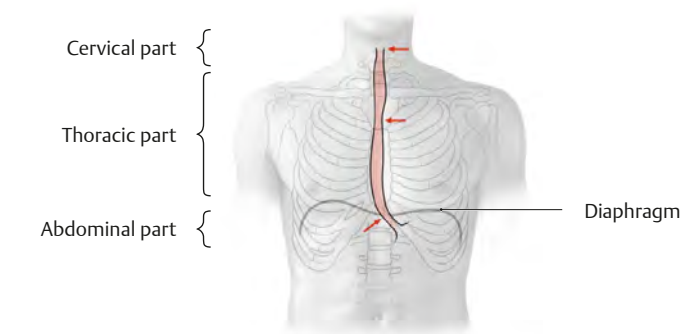


Esophagus

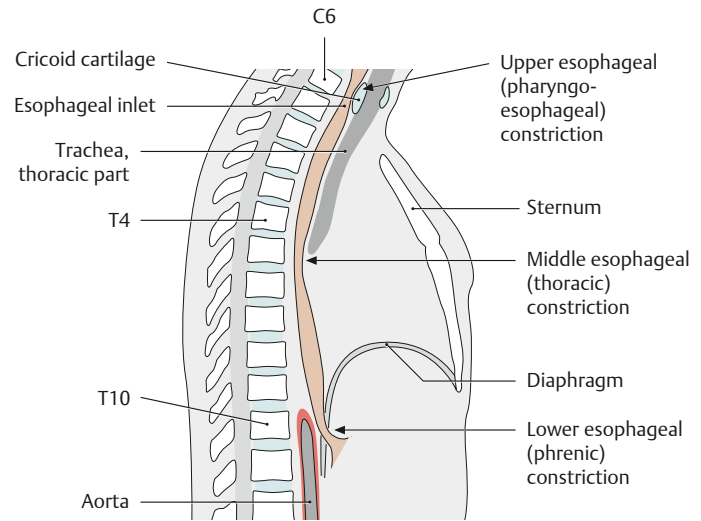
The esophagus is divided into three parts: cervical (C6–T1), thoracic (T1 to the esophageal hiatus of the diaphragm), and abdominal (the diaphragm to the cardiac orifice of the stomach). It descends slightly to

the right of the thoracic aorta and pierces the diaphragm slightly to the left, just below the xiphoid process of the sternum.

Fig. 9.22 Esophagus: Location and constrictions



A Projection of esophagus onto chest wall. Esophageal constrictions are indicated with arrows.



B Esophageal constrictions, right lateral view.

Fig. 9.23 Esophagus in situ

Anterior view.

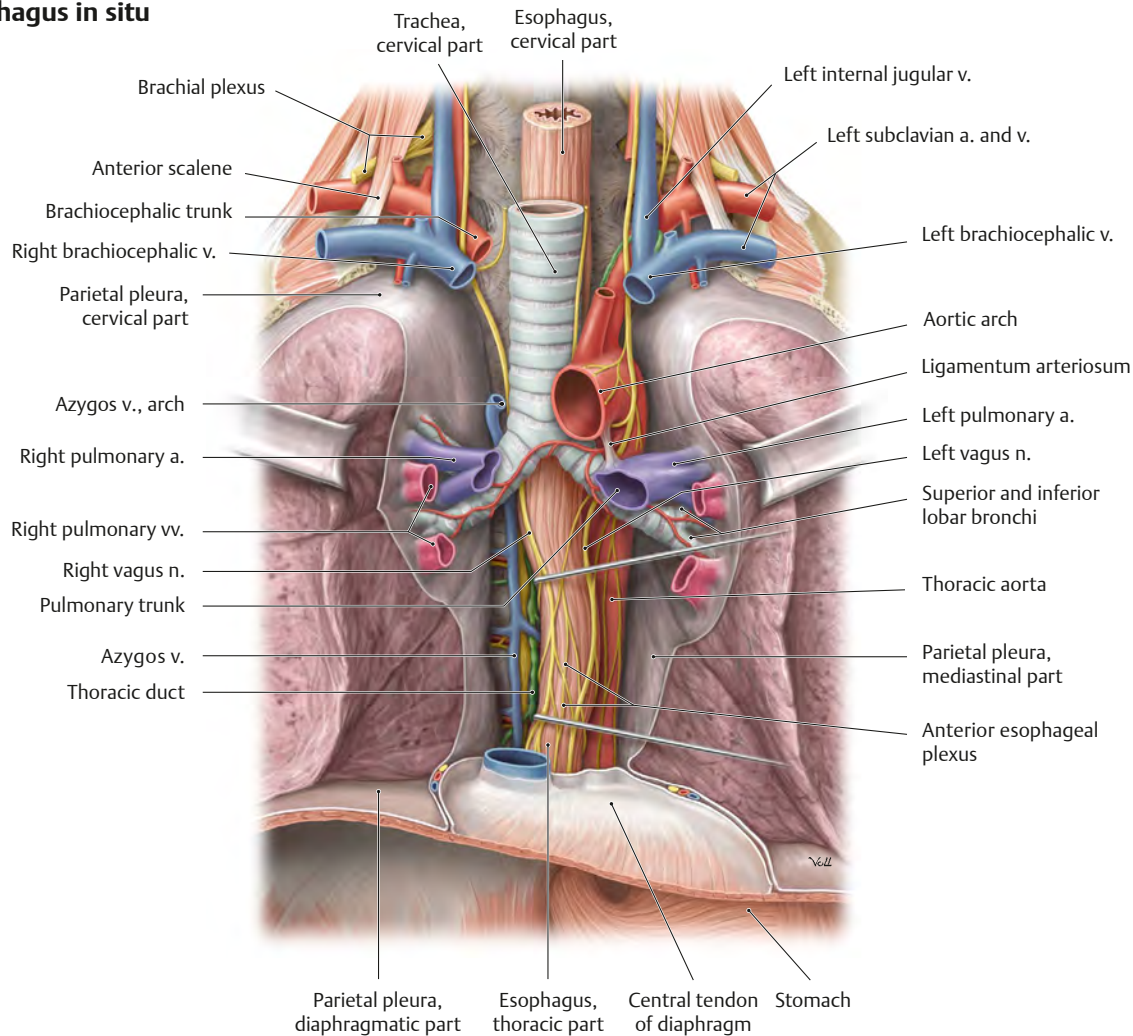
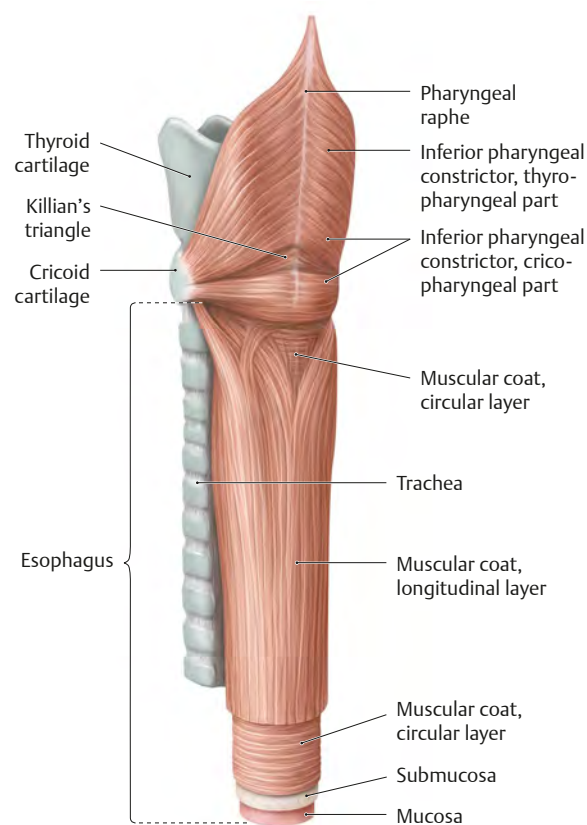
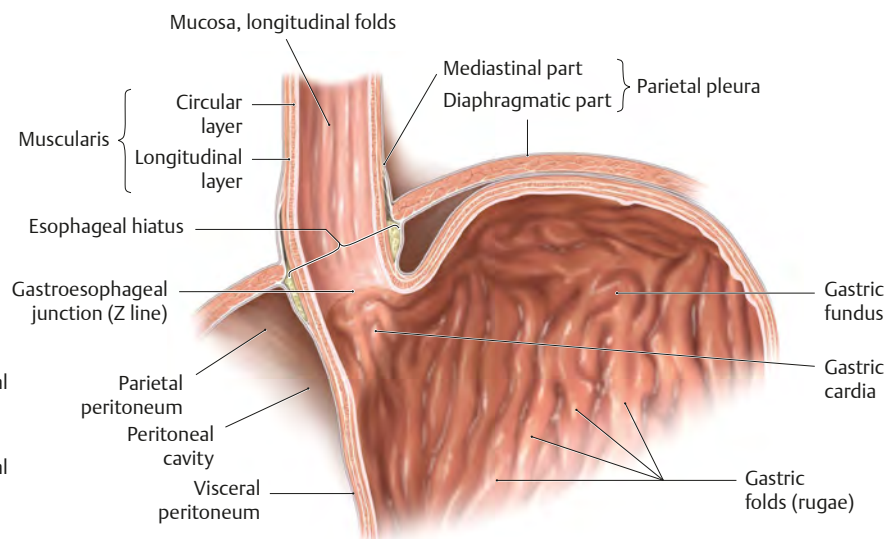
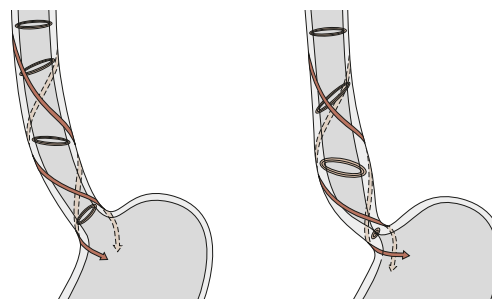
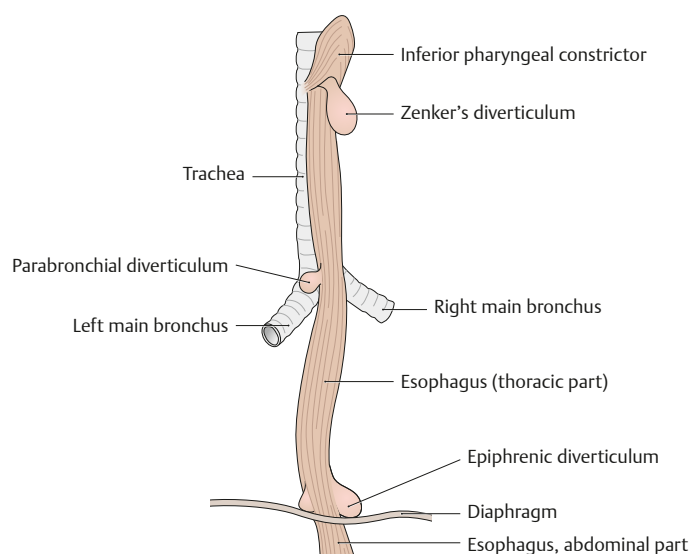


Fig. 9.24 Structure of the esophagus**A** Esophageal wall, oblique left posterior view. Pharynx (**p. 650**); trachea (**p. 120**).**B** Esophagogastric junction, anterior view. A true sphincter is not identifiable at this junction; instead, the diaphragmatic muscle of the esophageal hiatus functions as a sphincter. It is often referred to as the “Z line” because of its zigzag form.**C** Functional architecture of esophageal muscle.**Clinical box 9.6****Esophageal diverticula**

Diverticula (abnormal outpouchings or sacs) generally develop at weak spots in the esophageal wall. There are three main types of esophageal diverticula:

- Hypopharyngeal (pharyngo-esophageal) diverticula: Outpouchings occurring at the junction of the pharynx and the esophagus. These include Zenker's diverticula (70% of cases).
- “True” traction diverticula: Protrusion of all wall layers, not typically occurring at characteristic weak spots. However, they generally result from an inflammatory process (e.g., lymphangitis) and are thus common at sites where the esophagus closely approaches the bronchi and bronchial lymph nodes (thoracic or parabranchial diverticula).
- “False” pulsion diverticula: Herniations of the mucosa and submucosa through weak spots in the muscular coat due to a rise in esophageal pressure (e.g., during normal swallowing). These include paraesophageal and epiphrenic diverticula occurring above the esophageal aperture of the diaphragm (10% of cases).

Neurovasculature of the Esophagus

Sympathetic innervation: Preganglionic fibers arise from the T2–T6 spinal cord segments. Postganglionic fibers arise from the sympathetic trunk to join the esophageal plexus. Parasympathetic innervation: Preganglionic fibers arise from the dorsal vagal nucleus and travel in

the vagus nerves to form the extensive esophageal plexus. *Note:* The postganglionic neurons are in the wall of the esophagus. Fibers to the cervical portion of the esophagus travel in the recurrent laryngeal nerves.

Fig. 9.25 Autonomic innervation of the esophagus

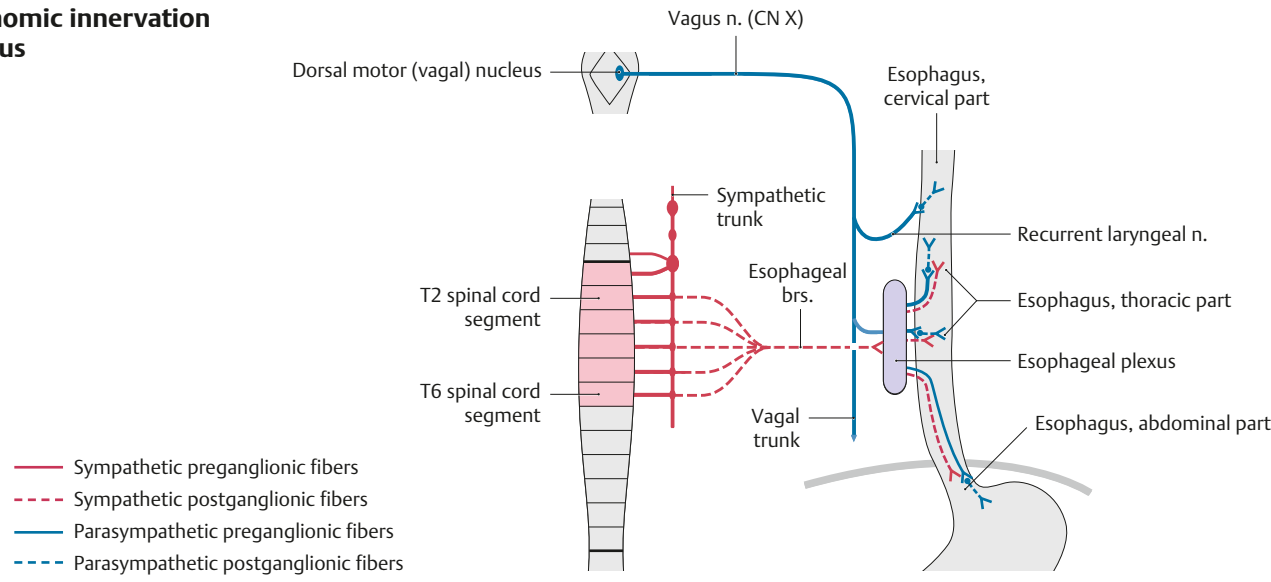
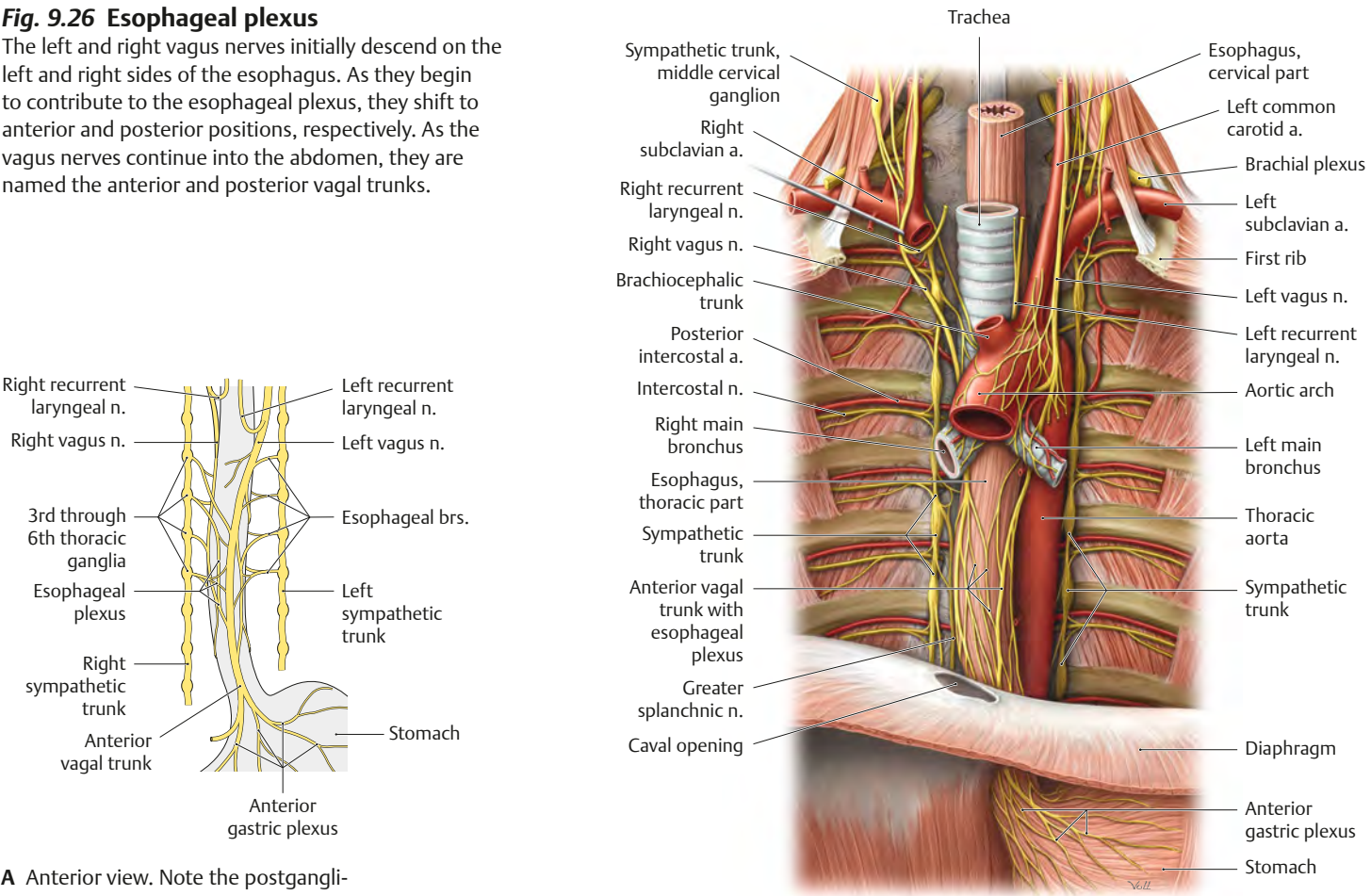


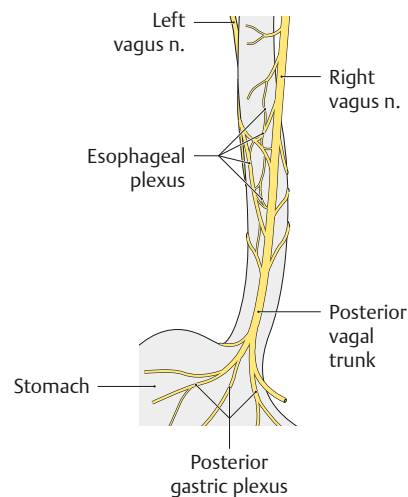
Fig. 9.26 Esophageal plexus

The left and right vagus nerves initially descend on the left and right sides of the esophagus. As they begin to contribute to the esophageal plexus, they shift to anterior and posterior positions, respectively. As the vagus nerves continue into the abdomen, they are named the anterior and posterior vagal trunks.



A Anterior view. Note the postganglionic sympathetic contribution to the esophageal plexus.

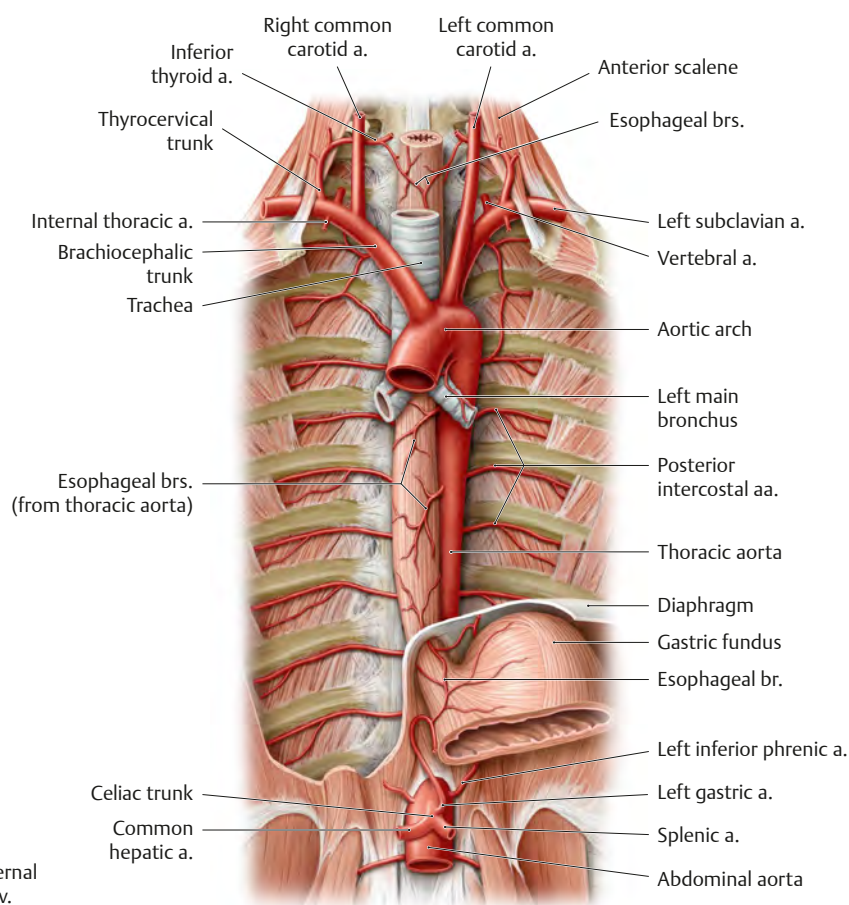
B Esophageal plexus in situ. Anterior view.



C Posterior view.

Fig. 9.27 Esophageal arteries

Anterior view.

**Fig. 9.28 Esophageal veins**

Anterior view.

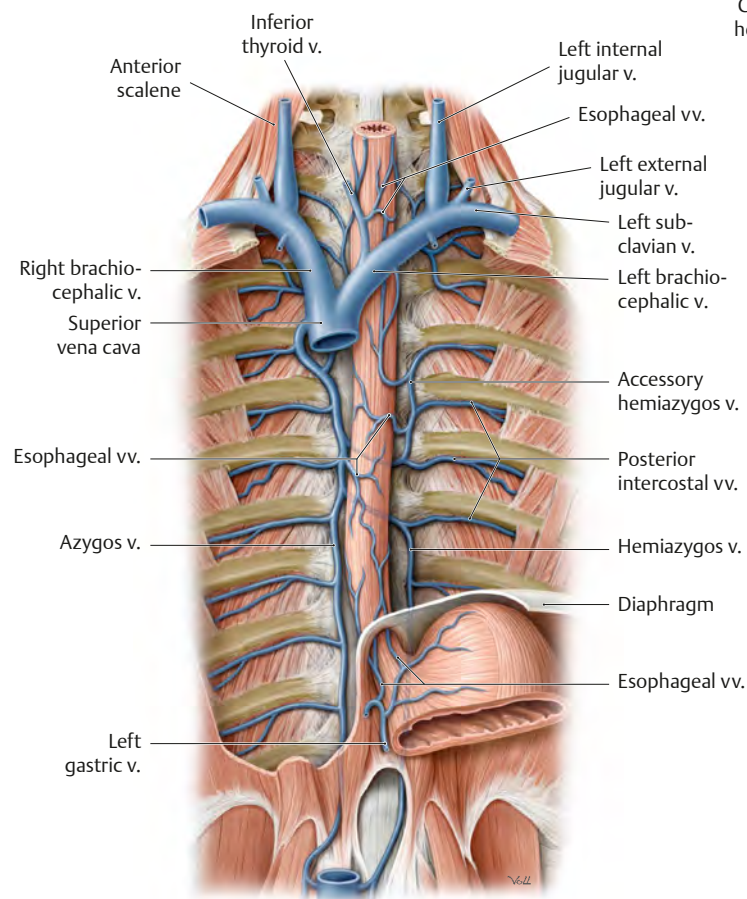


Table 9.6 Blood vessels of the esophagus		
Part	Origin of esophageal arteries	Drainage of esophageal veins
Cervical	Inferior thyroid a.	Inferior thyroid v.
	Rarely direct brs. from thyrocervical trunk or common carotid a.	Left brachiocephalic v.
Thoracic	Aorta (four or five esophageal aa.)	Upper left: Accessory hemiazygos v. or left brachiocephalic v.
		Lower left: Hemiazygos v.
		Right side: Azygos v.
Abdominal	Left gastric a.	Left gastric v.

Lymphatics of the Mediastinum

The superior phrenic lymph nodes drain lymph from the diaphragm, pericardium, lower esophagus, lung, and liver into the broncho-mediastinal trunk. The inferior phrenic lymph nodes, found in the

abdomen, collect lymph from the diaphragm and lower lobes of the lung and convey it to the lumbar trunk. *Note:* The pericardium may also drain superiorly to the brachiocephalic lymph nodes.

Fig. 9.29 Lymph nodes of the mediastinum and thoracic cavity
Left anterior oblique view.

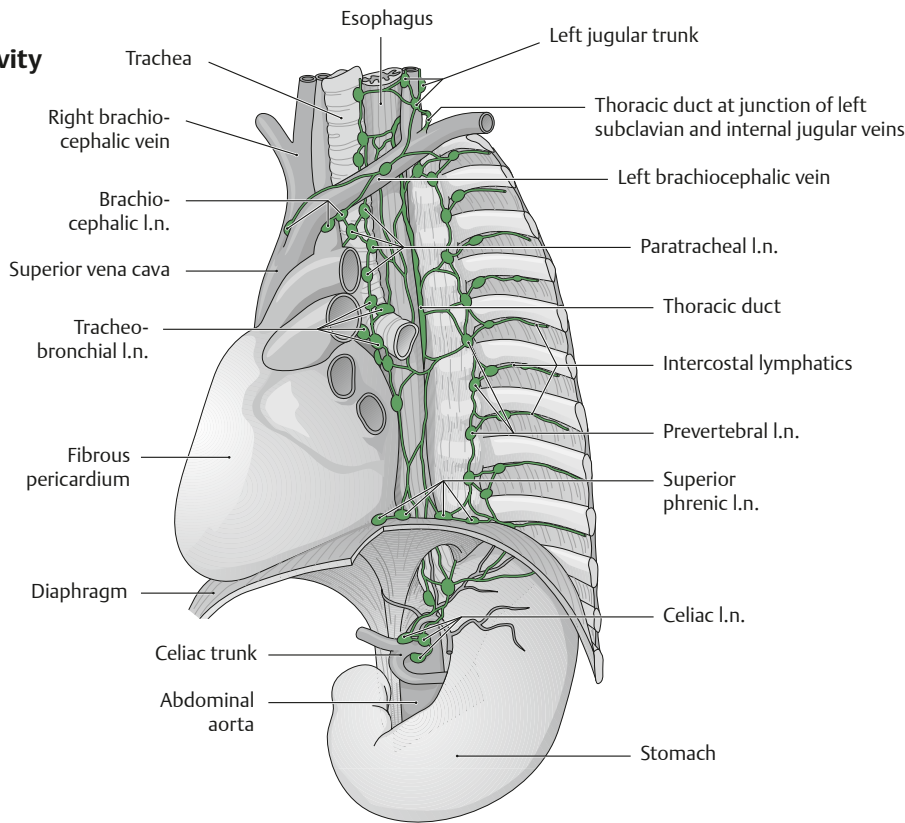
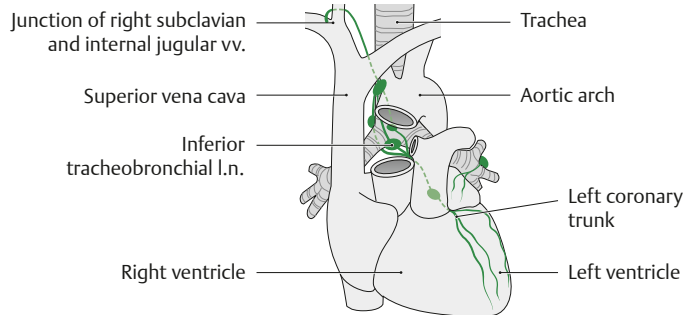
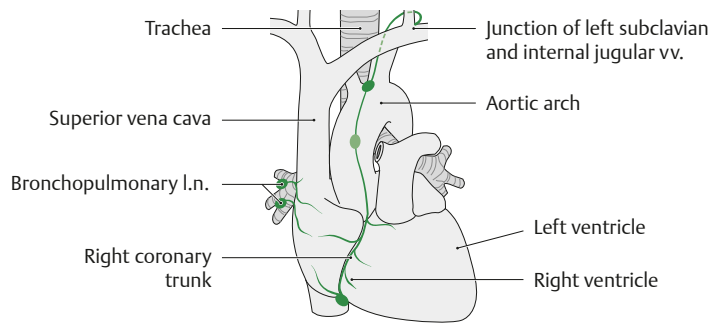


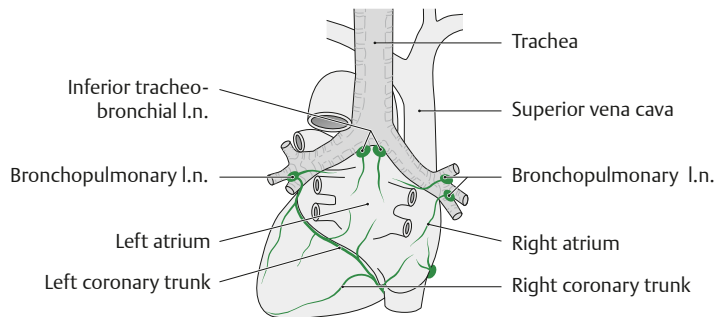
Fig. 9.30 Lymphatic drainage of the heart

A unique “crossed” drainage pattern exists in the heart: lymph from the left atrium and ventricle drains to the right venous junction, whereas lymph from the right atrium and ventricle drains to the left venous junction.



A Lymphatic drainage of the left chambers, anterior view.

B Lymphatic drainage of the right chambers, anterior view.

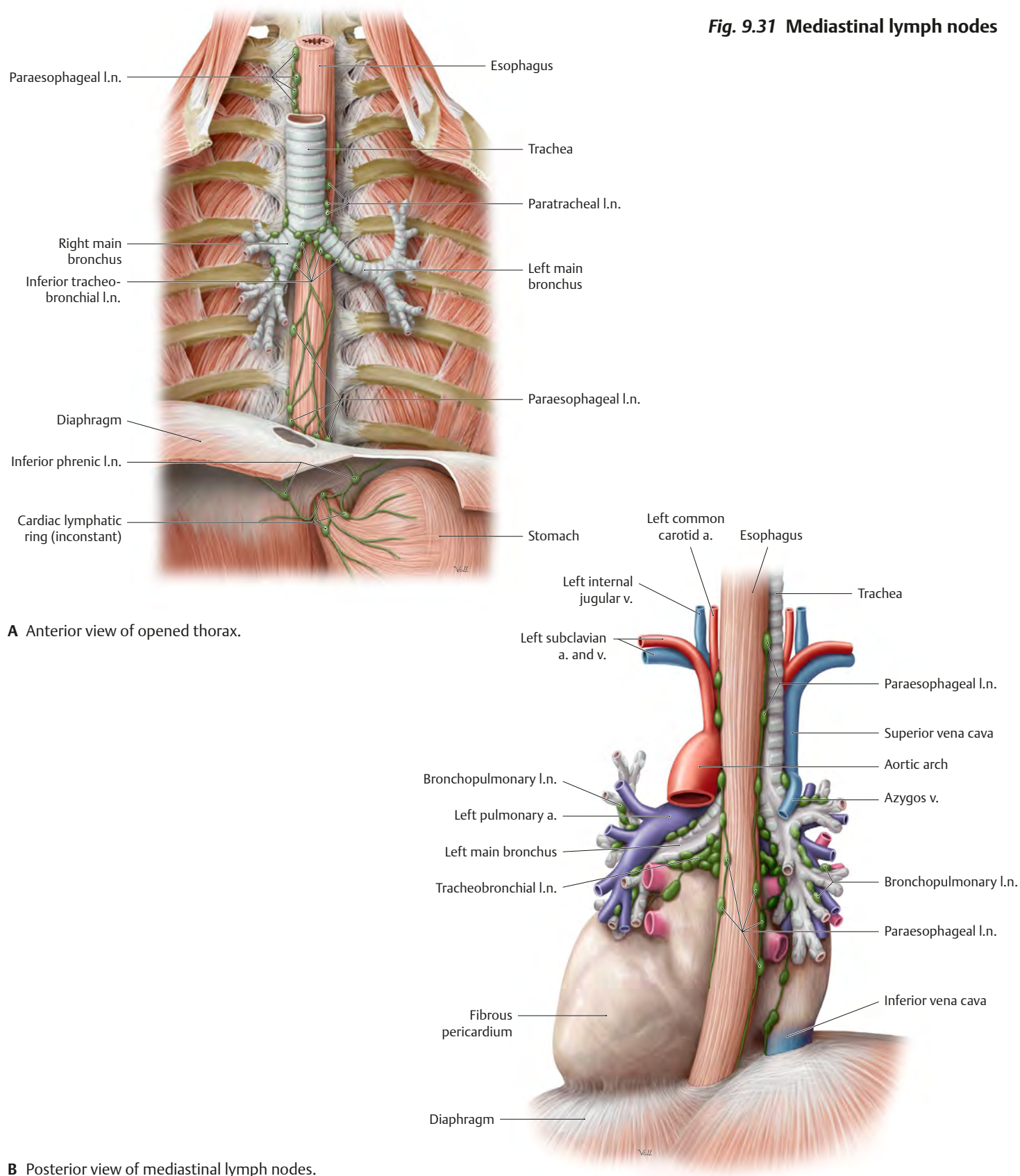


C Posterior view.

The paraesophageal nodes drain the esophagus. Lymphatic drainage of the cervical part of the esophagus is primarily cranial, to the deep cervical lymph nodes and then to the jugular trunk. The thoracic part of the esophagus drains to the bronchomediastinal trunks in two parts:

the upper half drains cranially, and the lower half drains inferiorly via the superior phrenic lymph nodes. The bronchopulmonary and paratracheal nodes drain lymph from the lungs, bronchi, and trachea into the bronchomediastinal trunk (see p. 128).

Fig. 9.31 Mediastinal lymph nodes



10 Pulmonary Cavities

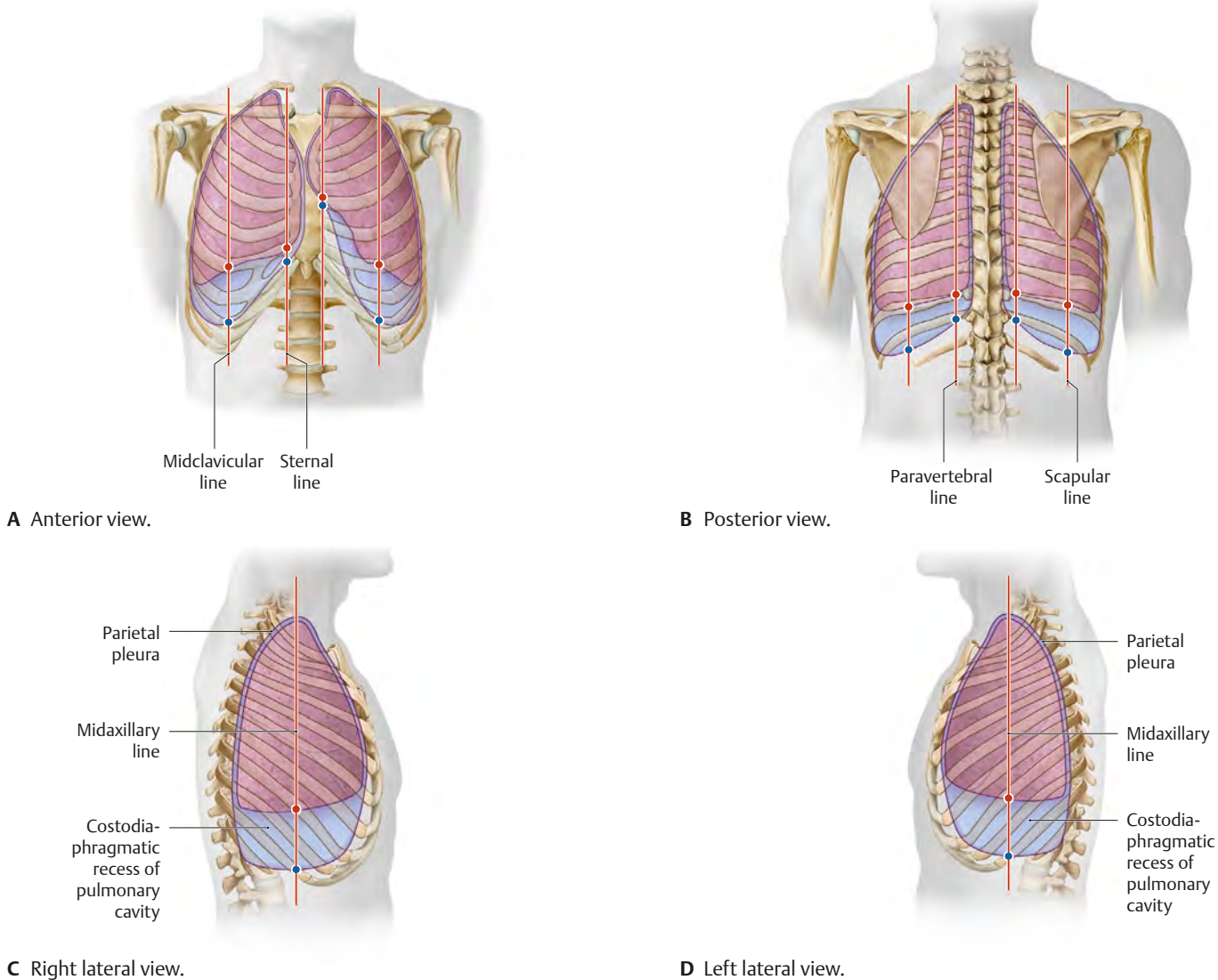
Pulmonary Cavities

The paired pulmonary cavities contain the left and right lungs. They are completely separated from each other by the mediastinum and are under negative atmospheric pressure (see respiratory mechanics, pp. 122–123). The left pulmonary cavity is slightly smaller than the right, especially anteriorly, due to the asymmetrical position of the

heart in the mediastinum, with the greater mass on the left. This causes a shift of some of the boundaries of the parietal pleura and lung on the left side at the level of the heart, as reflected in the difference in thoracic landmarks found at the intersection of the anterior border of the pulmonary cavities with certain reference lines on the left and right.

Fig. 10.1 Boundaries of the lungs and pulmonary cavities

The upper red dot on each reference line is the inferior boundary of the lung and the lower blue dot is the inferior boundary of the pulmonary cavity.

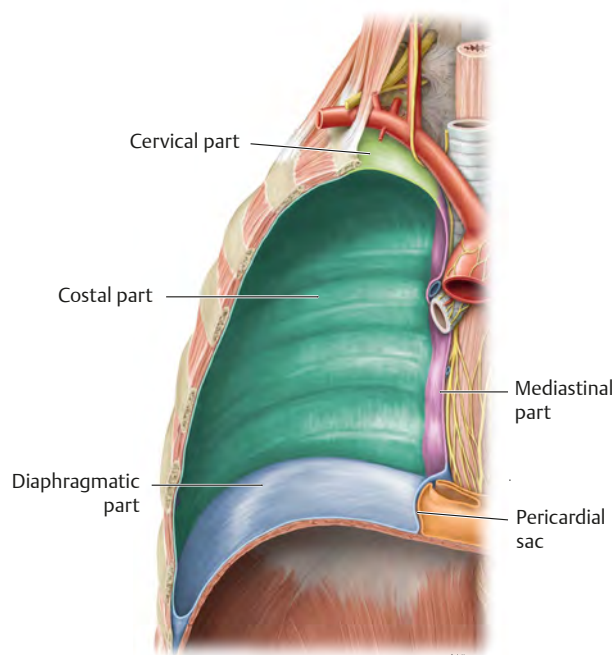


Reference line	Right lung	Right parietal pleura	Left lung	Left parietal pleura
Sternal line (STL)	6 th rib	7 th rib	4 th rib	4 th rib
Midclavicular line (MCL)	6 th rib	8 th costal cartilage	6 th rib	8 th rib
Midaxillary line (MAL)	8 th rib	10 th rib	8 th rib	10 th rib
Scapular line (SL)	10 th rib	11 th rib	10 th rib	11 th rib
Paravertebral line (PV)	10 th rib	T12 vertebra	10 th rib	T12 vertebra

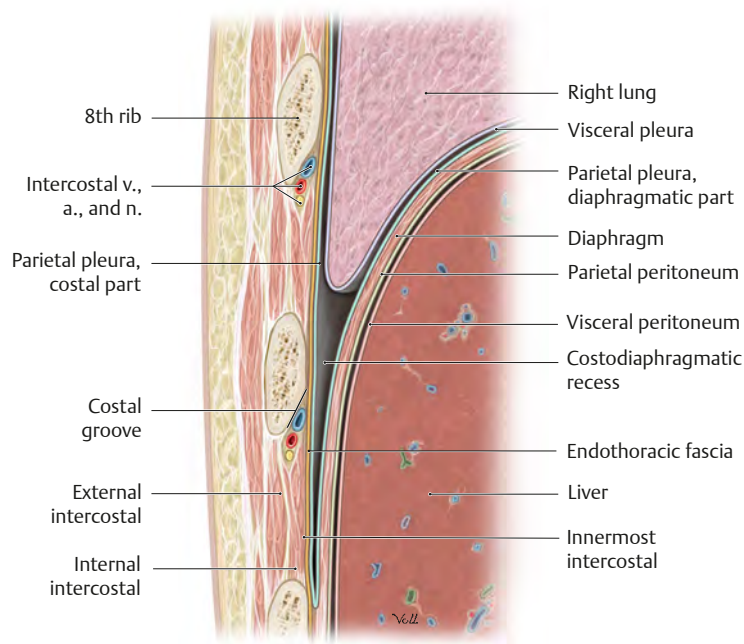
Fig. 10.2 Parietal pleura

The pulmonary cavity is bounded by two serous layers. The visceral pleura covering the lungs, and parietal pleura lining the inner surfaces

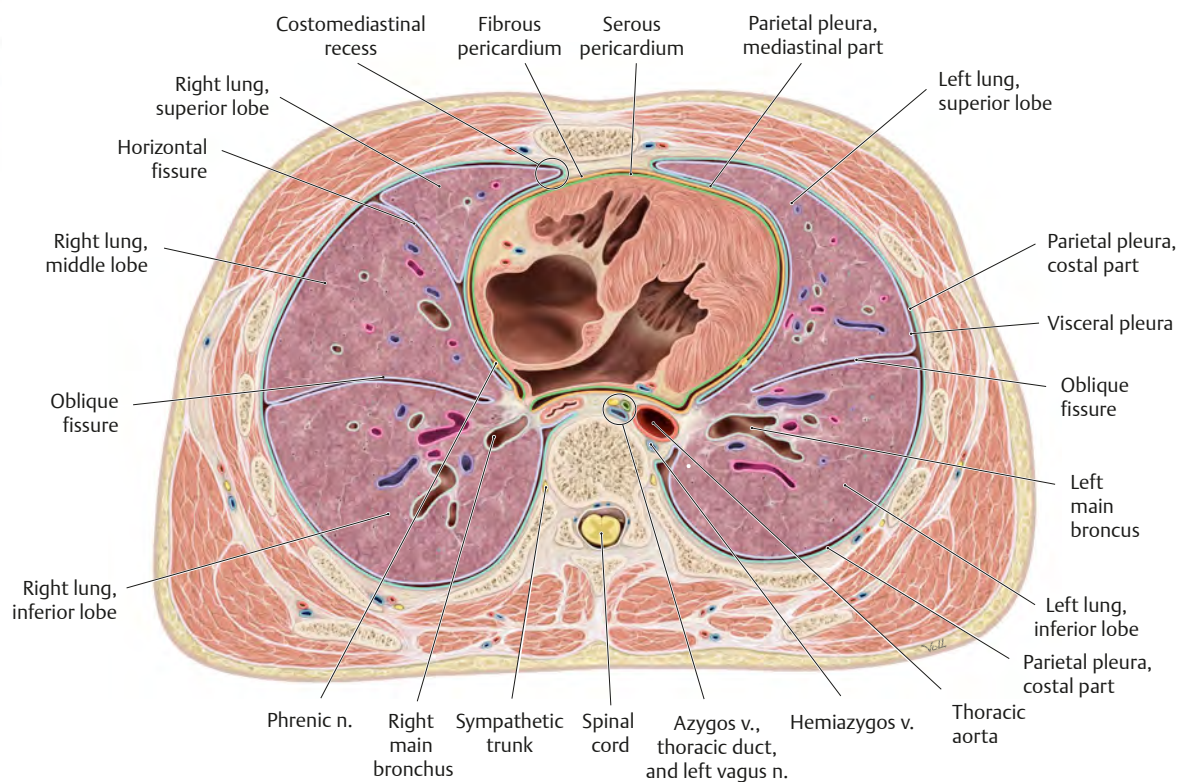
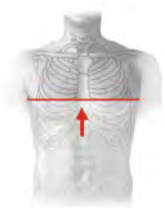
of the thoracic cavity. The four divisions of the parietal pleura (costal, diaphragmatic, mediastinal, and cervical) are continuous.



A Parts of the parietal pleura. *Opened*: Right pleural cavity, anterior view.



B Costodiaphragmatic recess, coronal section, anterior view. Reflection of the diaphragmatic pleura onto the inner thoracic wall (becoming the costal pleura) forms the costodiaphragmatic recess.



C Transverse section at T7, inferior view. Reflection of the costal pleura onto the pericardium forms the costomediastinal recess.

Pleura: Subdivisions, Recesses & Innervation

Fig. 10.3 Pleura and its divisions

The anterior thoracic wall and costal portion of the parietal pleura have been removed to show the lungs in situ.

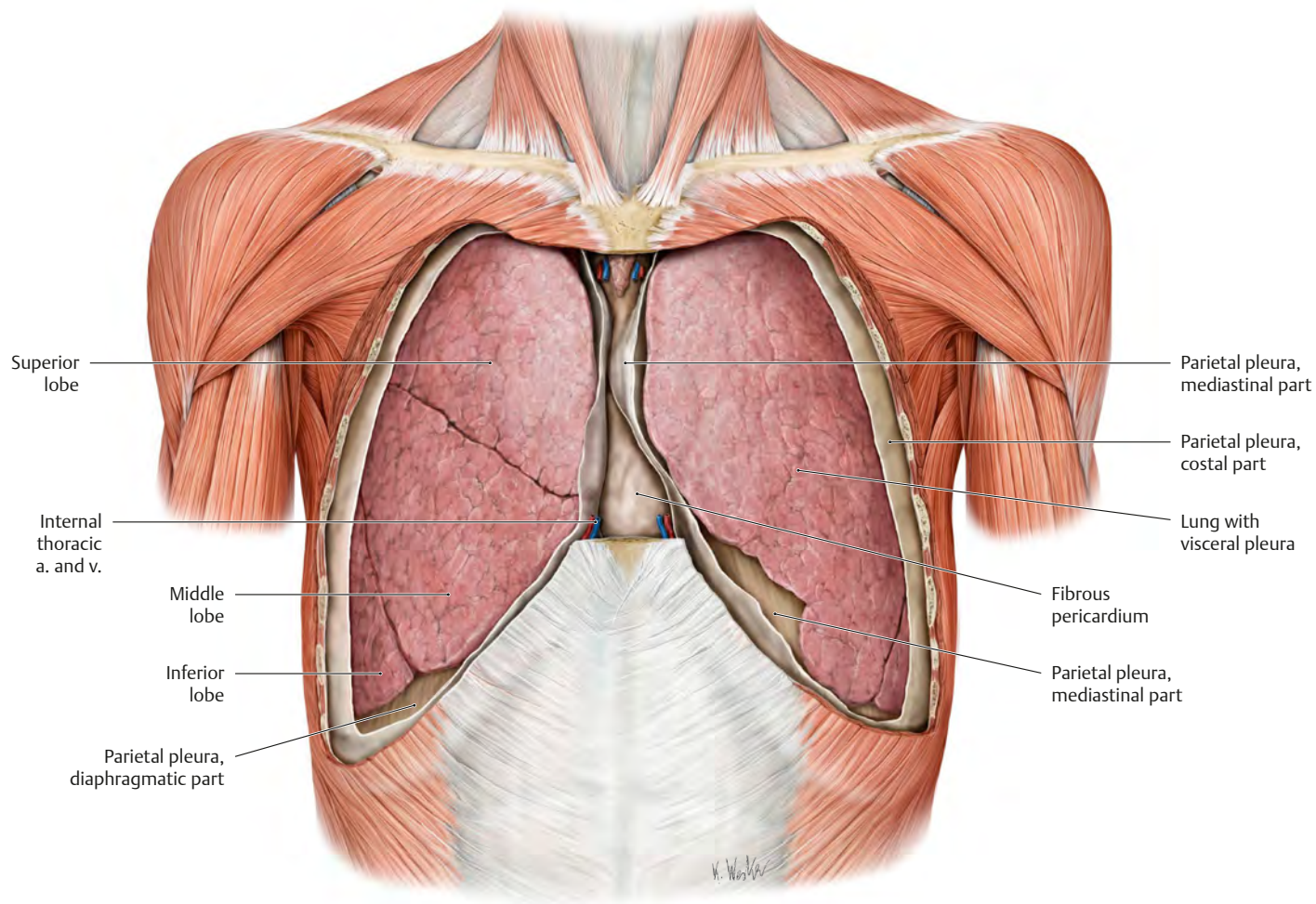


Fig. 10.4 Innervation of the pleura

The costal and cervical portions and the periphery of the diaphragmatic portion of the parietal pleura are innervated by the intercostal nerves. The mediastinal and central portions of the diaphragmatic pleura are innervated by the phrenic nerves. The visceral pleura covering the lung itself receives its innervation from the autonomic nervous system.

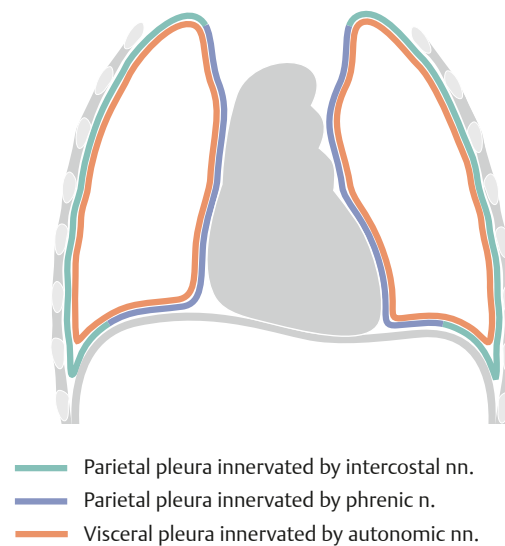
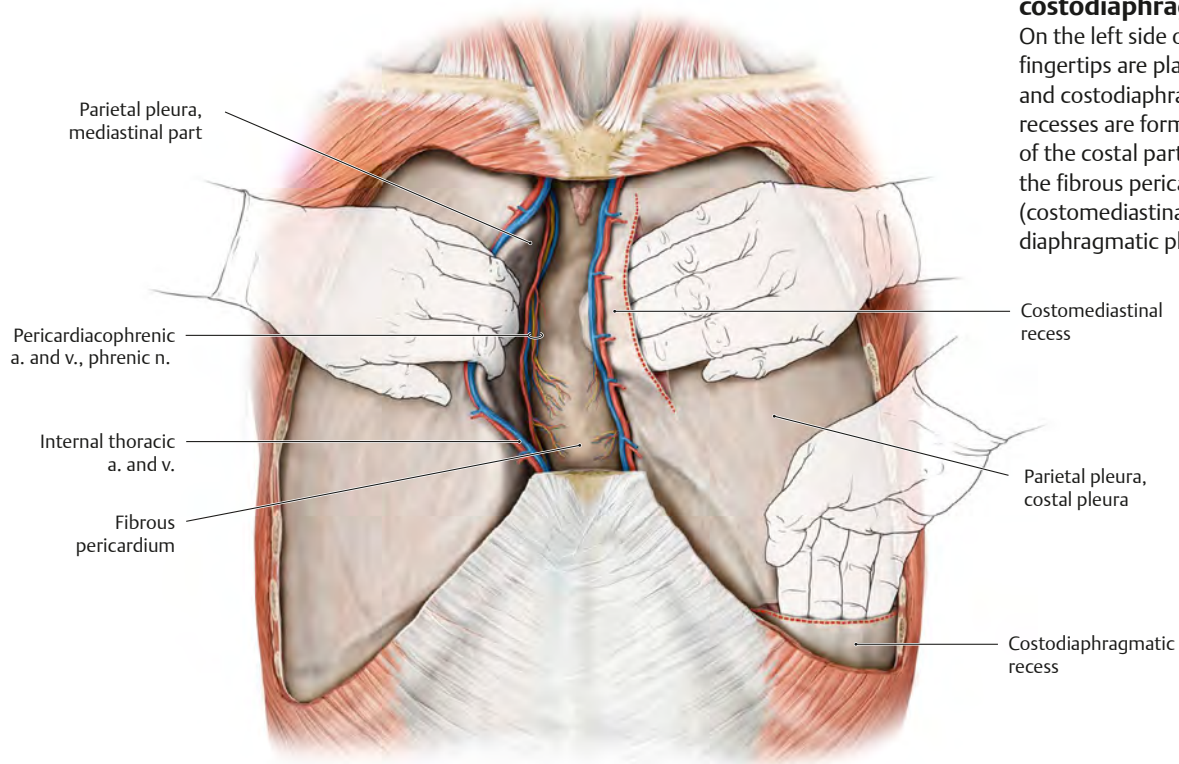
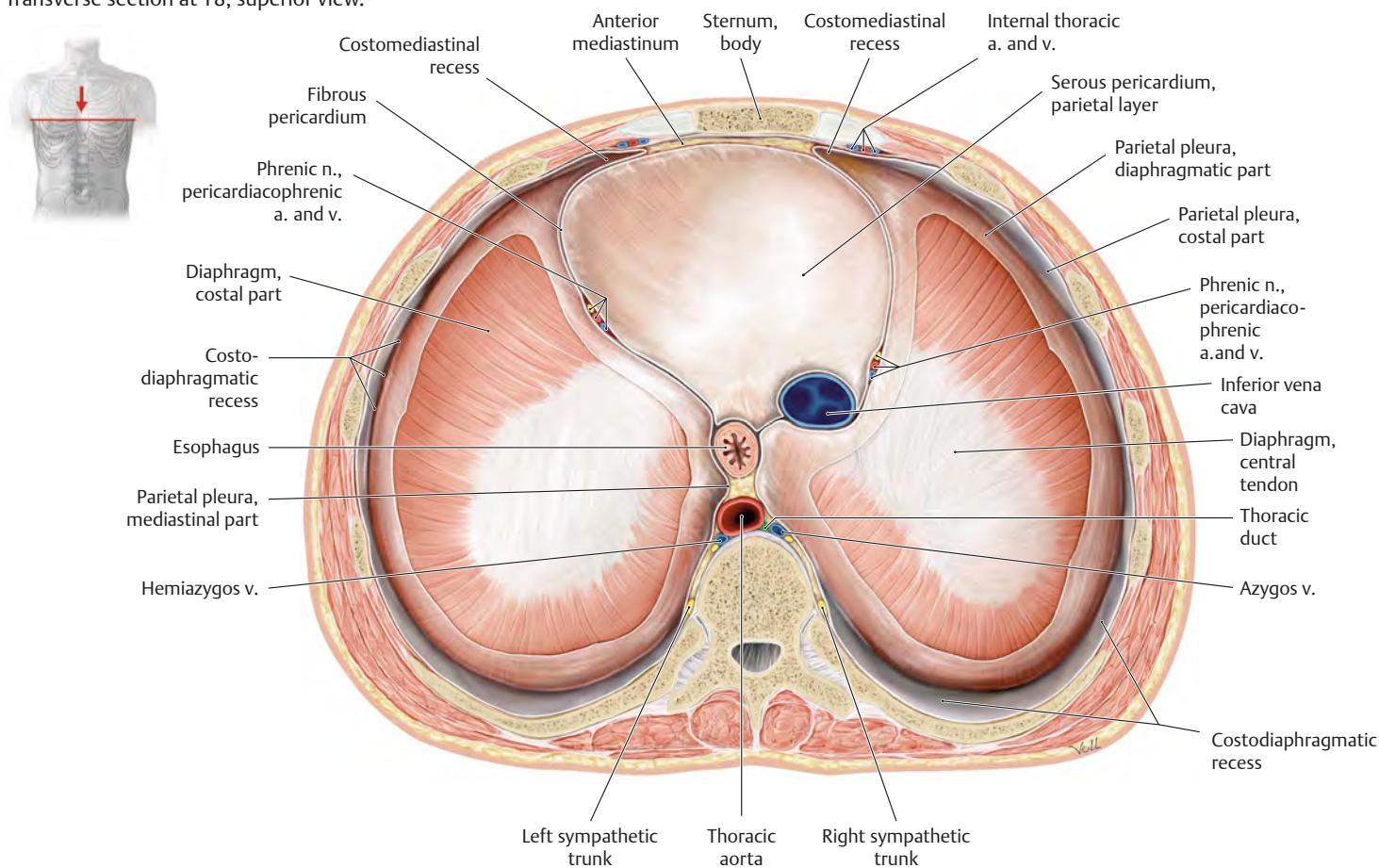


Fig. 10.5 Costomediastinal and costodiaphragmatic recesses

On the left side of the thorax, an examiner's fingertips are placed in the costomediastinal and costodiaphragmatic recesses. These recesses are formed by the acute reflection of the costal part of the parietal pleura onto the fibrous pericardium as mediastinal pleura (costomediastinal) or on to the diaphragm as diaphragmatic pleura (costodiaphragmatic).

**Fig. 10.6 Pleural recesses**

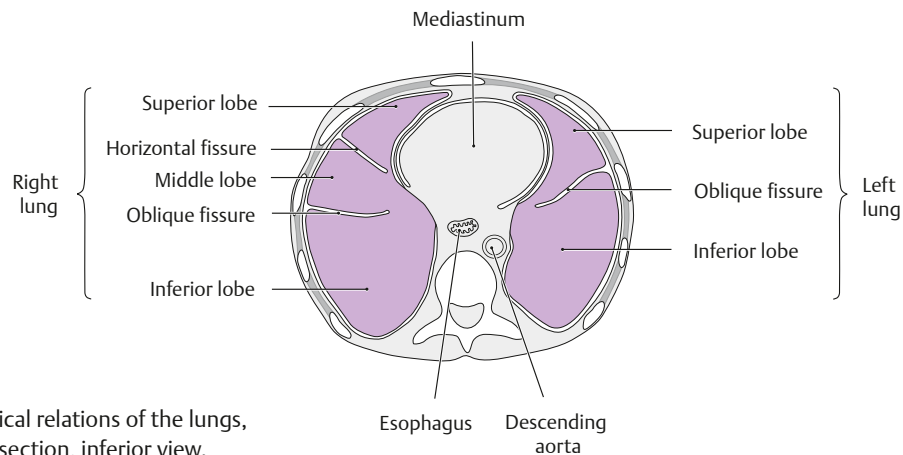
Transverse section at T8, superior view.



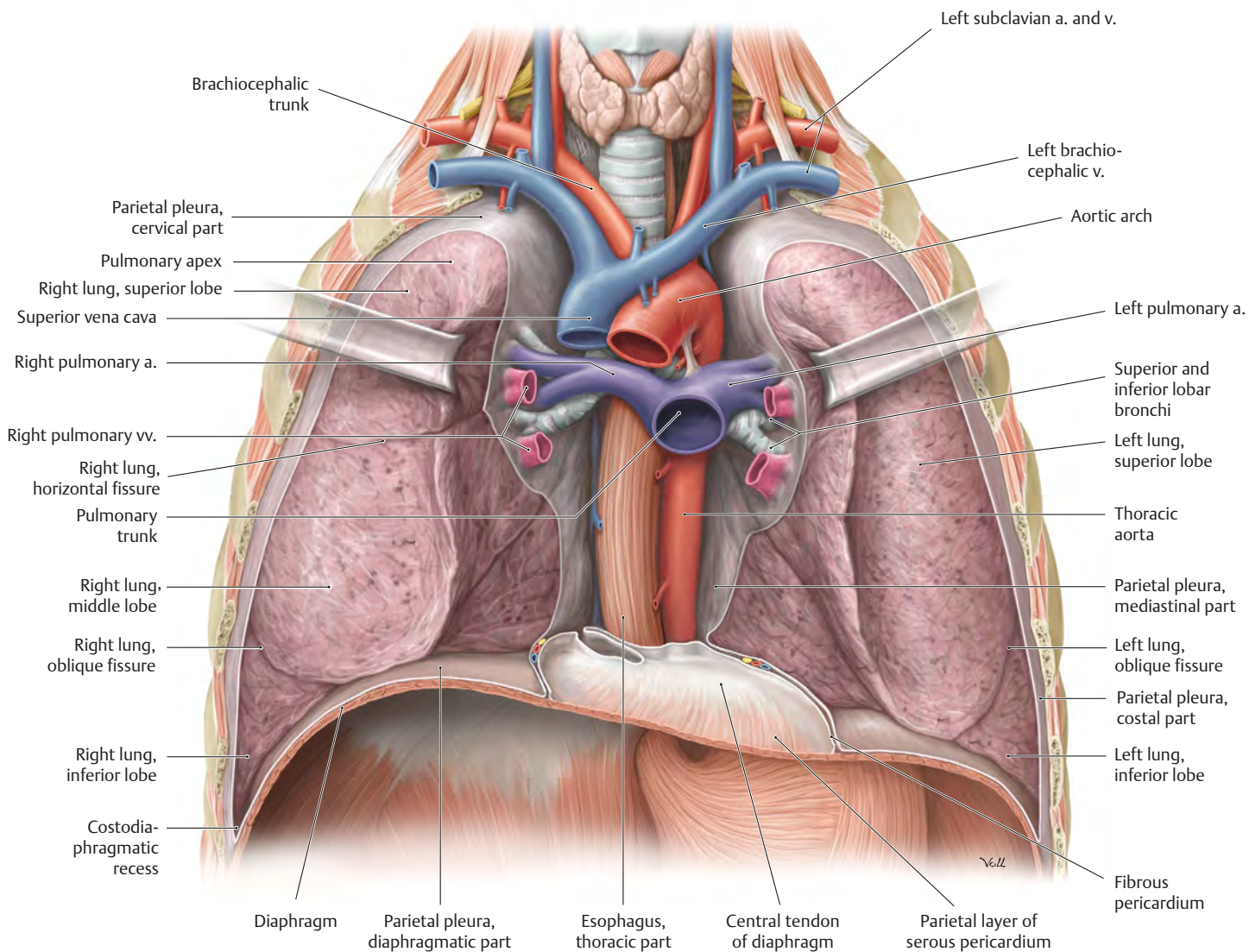
Lungs

Fig. 10.7 Lungs in situ

The left and right lungs occupy the full volume of the pleural cavity. Note that the left lung is slightly smaller than the right due to the asymmetrical position of the heart.



A Topographical relations of the lungs, transverse section, inferior view.

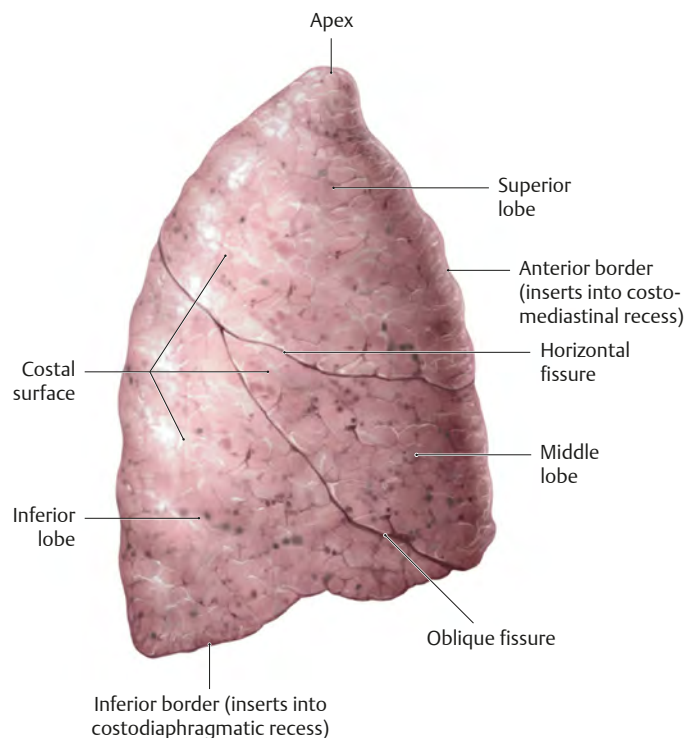


B Anterior view with lungs retracted.

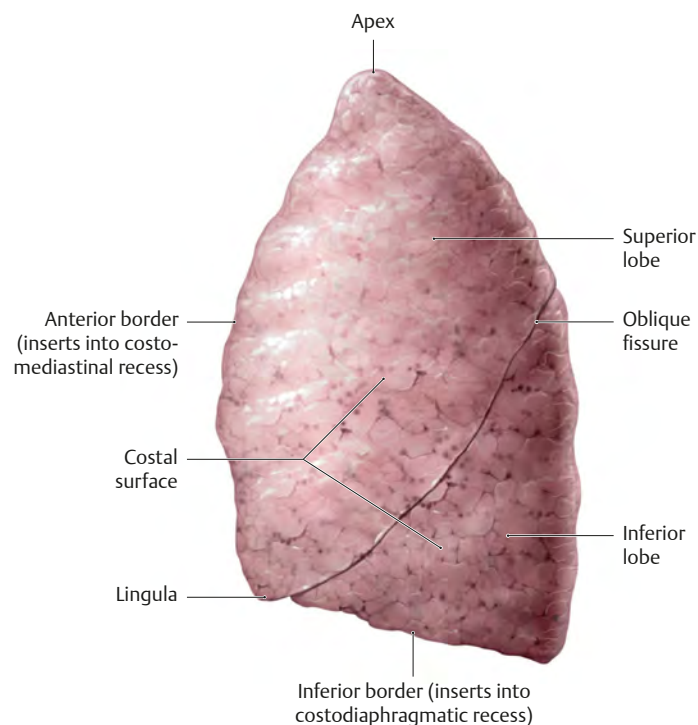
Fig. 10.8 Gross anatomy of the lungs

The oblique and horizontal fissures divide the right lung into three lobes: superior, middle, and inferior. The oblique fissure divides the left lung into two lobes: superior and inferior. The apex of each lung

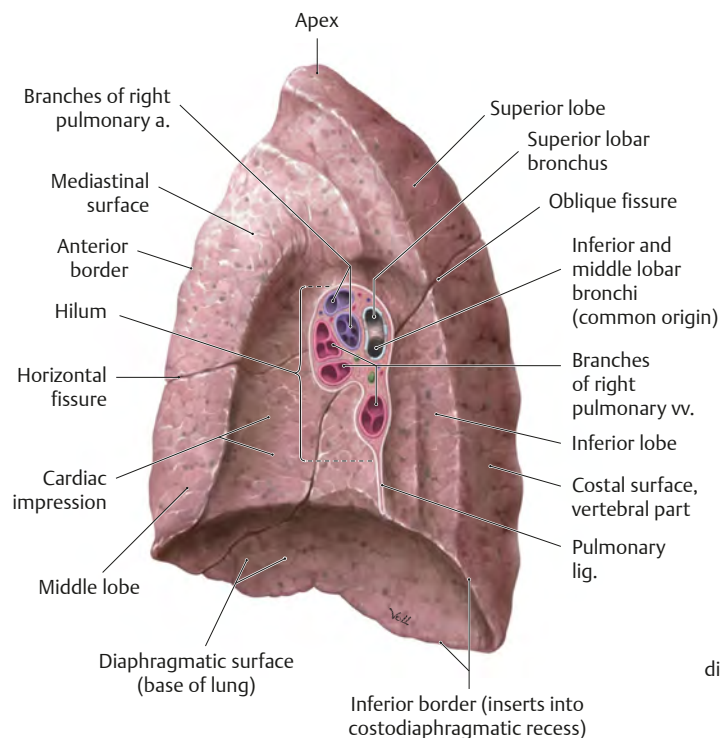
extends into the root of the neck. The hilum is the location at which the bronchi and neurovascular structures connect to the lung.



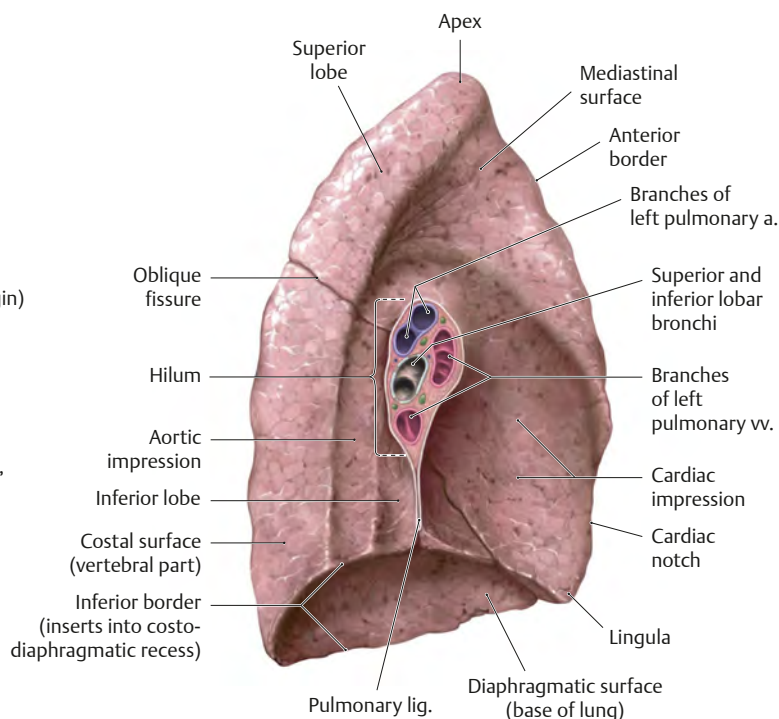
A Right lung, lateral view.



B Left lung, lateral view.



C Right lung, medial view.



D Left lung, medial view.

Bronchopulmonary Segments of the Lungs

The lung lobes are subdivided into bronchopulmonary segments, the smallest resectable portion of a lung, each supplied by a tertiary

(segmental) bronchus. *Note:* These subdivisions are not defined by surface boundaries but by origin.

Fig. 10.9 Segmentation of the lung
Anterior view. See pp. 120–121 for details of the trachea and bronchial tree.

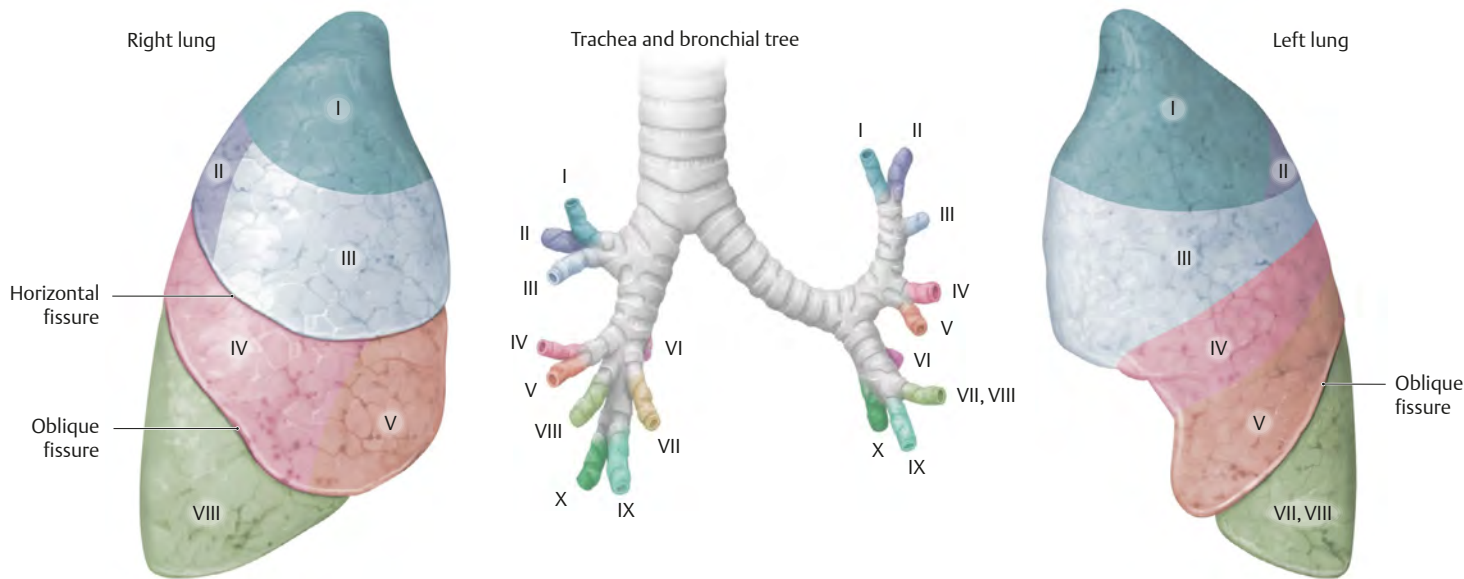


Fig. 10.10 Anteroposterior bronchogram
Anterior view of right lung.



Table 10.2		Segmental architecture of the lungs	
Each segment is supplied by a segmental bronchus of the same name (e.g., the apical segmental bronchus supplies the apical segment). See pp. 120–121 for details of the trachea and bronchial tree.			
Right lung		Left lung	
Superior lobe			
I	Apical segment	Apicoposterior segment	I
II	Posterior segment		II
III	Anterior segment		III
Middle lobe		Lingula	
IV	Lateral segment	Superior lingular segment	IV
V	Medial segment	Inferior lingular segment	V
Inferior lobe			
VI	Superior segment		VI
VII	Medial basal segment		VII
VIII	Anterior basal segment		VIII
IX	Lateral basal segment		IX
X	Posterior basal segment		X

Fig. 10.11 Right lung: Bronchopulmonary segments

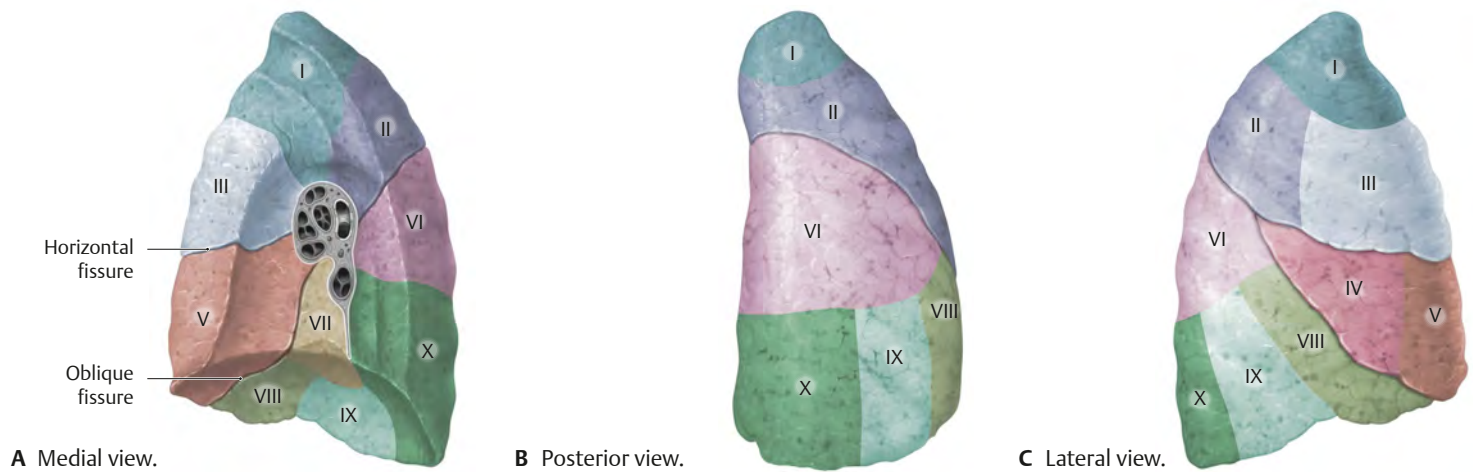
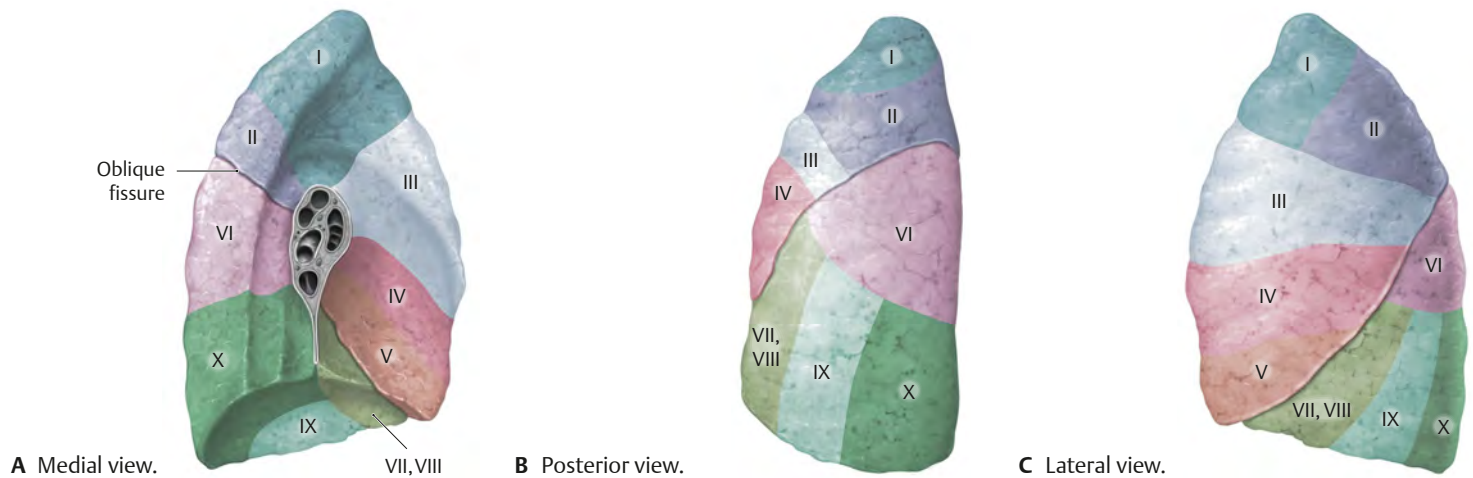


Fig. 10.12 Left lung: Bronchopulmonary segments

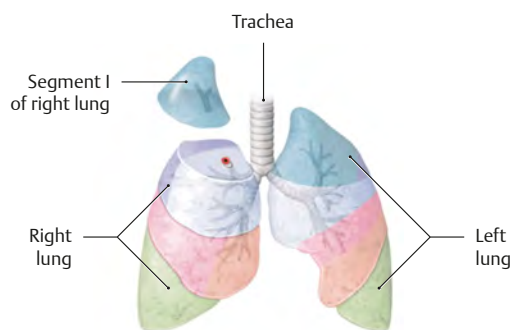


Clinical box 10.1

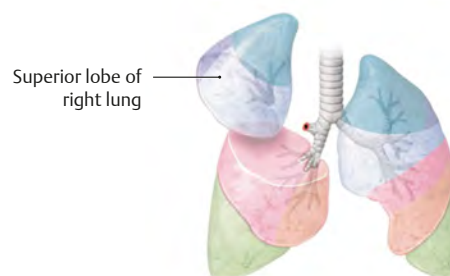
Lung resections

Lung cancer, emphysema, or tuberculosis may necessitate the surgical removal of damaged portions of the lung. Surgeons exploit the anatomical

subdivision of the lungs into lobes and segments when excising damaged tissue.



A Segmentectomy (wedge resection): Removal of one or more segments.



B Lobectomy: Removal of lobe.



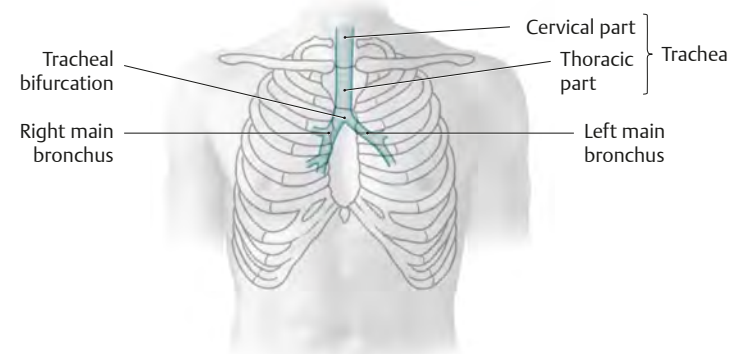
C Pneumonectomy: Removal of entire lung.

At or near the level of the sternal angle (T4/T5), the lowest tracheal cartilage extends anteroposteriorly, forming the carina. The trachea

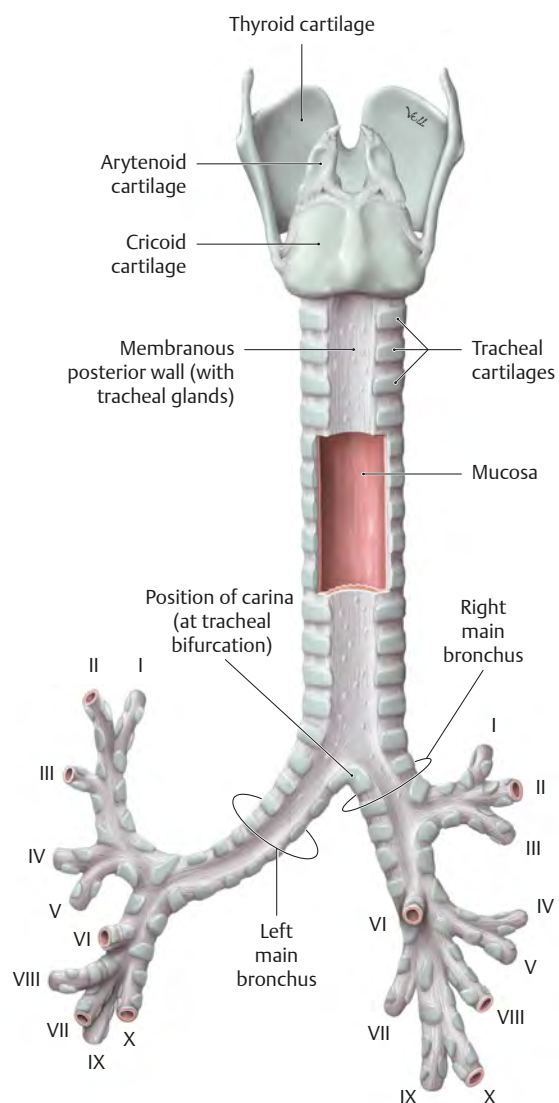
bifurcates at the carina into the right and left main bronchi. Each bronchus gives off lobar branches to the corresponding lung.

Fig. 10.13 Trachea

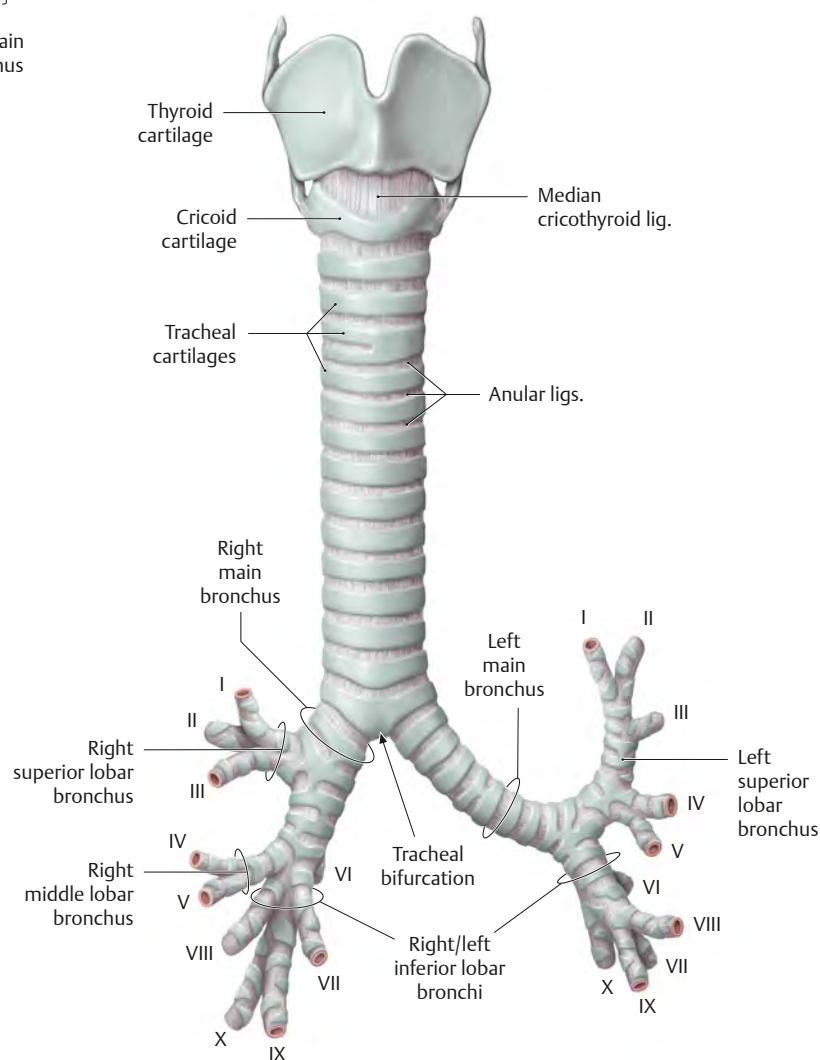
See **p. 530** for the structures of the thyroid.



A Projection of trachea onto chest.



C Posterior view with opened posterior wall.



B Anterior view.



Clinical box 10.2

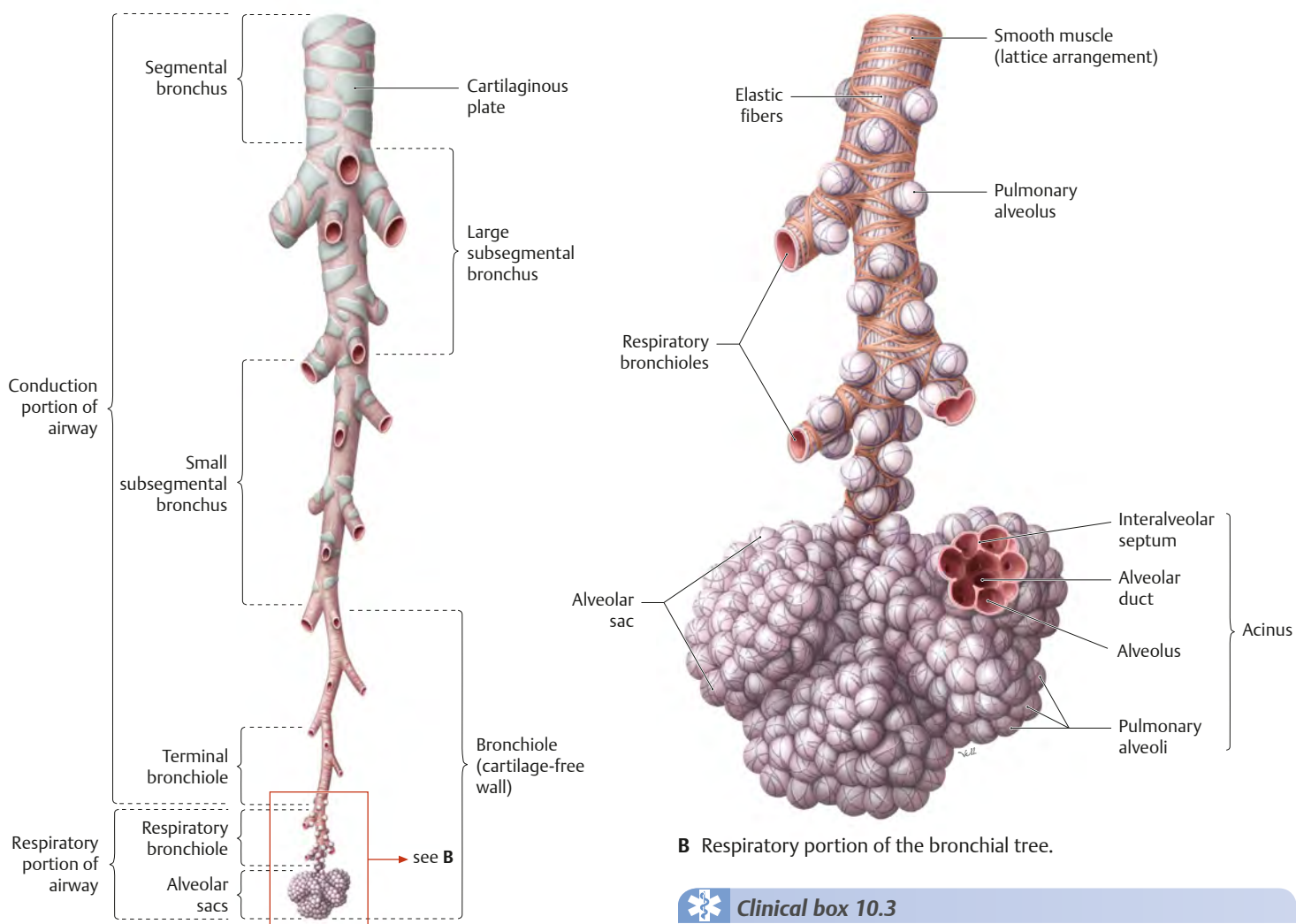
Foreign body aspiration

Toddlers are at particularly high risk of potentially fatal aspiration of foreign bodies. In general, foreign bodies are more likely to become lodged in the right main bronchus than the left: the left bronchus diverges more sharply at the tracheal bifurcation to pass more horizontally over the heart, whereas the right bronchus is relatively straight and more in line with the trachea.

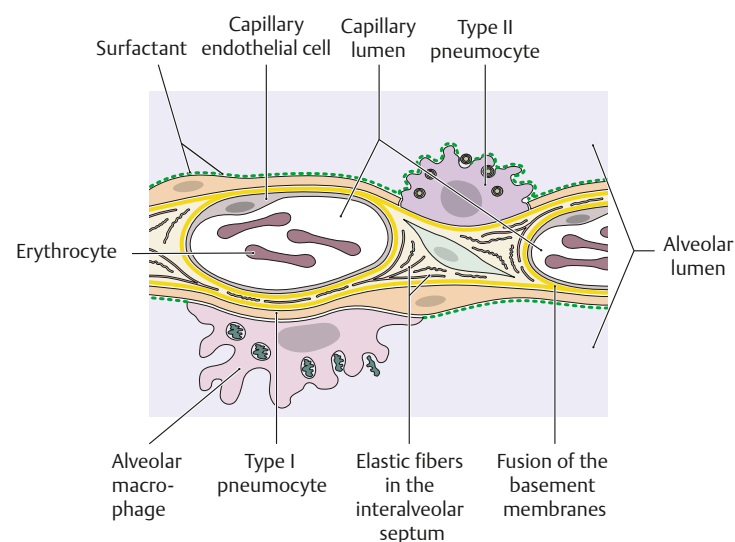
The conducting portion of the bronchial tree extends from the tracheal bifurcation to the terminal bronchiole, inclusive. The respiratory portion

consists of the respiratory bronchiole, alveolar ducts, alveolar sacs, and alveoli.

Fig. 10.14 Bronchial tree



A Divisions of the bronchial tree.



C Epithelial lining of the alveoli.



Clinical box 10.3

Respiratory compromise

The most common cause of respiratory compromise at the bronchial level is asthma. Compromise at the alveolar level may result from increased diffusion distance, decreased aeration (emphysema), or fluid infiltration (e.g., pneumonia).

Diffusion distance: Gaseous exchange takes place between the alveolar and capillary lumens in the alveoli (see Fig. 10.14C). At these sites, the basement membranes of capillary endothelial cells are fused with those of type I alveolar epithelial cells, lowering the exchange distance to 0.5 μm . Diseases that increase this diffusion distance (e.g., edematous fluid collection or inflammation) result in compromised respiration.

Condition of alveoli: In diseases like emphysema, which occurs in chronic obstructive pulmonary disease (COPD), alveoli are destroyed or damaged. This reduces the surface area available for gaseous exchange.

Production of surfactant: Surfactant is a protein-phospholipid film that lowers the surface tension of the alveoli, making it easier for the lung to expand. The immature lungs of a preterm infant often fail to produce sufficient surfactant, leading to respiratory problems. Surfactant is produced and absorbed by alveolar epithelial cells (pneumocytes). Type I alveolar epithelial cells absorb surfactant; type II produce and release it.

Respiratory Mechanics

The mechanics of respiration are based on a rhythmic increase and decrease in thoracic volume, with an associated expansion and contraction of the lungs. *Inspiration* (red): Contraction of the diaphragm leaflets lowers the diaphragm into the inspiratory position, increasing the volume of the pleural cavity along the vertical axis. Contraction of the thoracic muscles (external intercostals with the scalene, intercartilaginous, and posterior serratus muscles) elevates the ribs, expanding the pleural cavity along the sagittal and transverse axes (**Fig. 10.16A,B**). Surface tension in the pleural space causes the visceral and parietal pleura to adhere; thus, changes in thoracic volume alter the volume of the lungs. This is particularly evident in the pleural recesses: at functional residual capacity

(resting position between inspiration and expiration), the lung does not fully occupy the pleural cavity. As the pleural cavity expands, a negative intrapleural pressure is generated. The air pressure differential results in an influx of air (inspiration). *Expiration* (blue): During passive expiration, the muscles of the thoracic cage relax and the diaphragm returns to its expiratory position. Contraction of the lungs increases the pulmonary pressure and expels air from the lungs. For forcible expiration, the internal intercostal muscles (with the transverse thoracic and subcostal mucosa) can actively lower the rib cage more rapidly and to a greater extent than through passive elastic recoil.

Fig. 10.15 Respiratory changes in thoracic volume
Inspiratory position (red); expiratory position (blue).

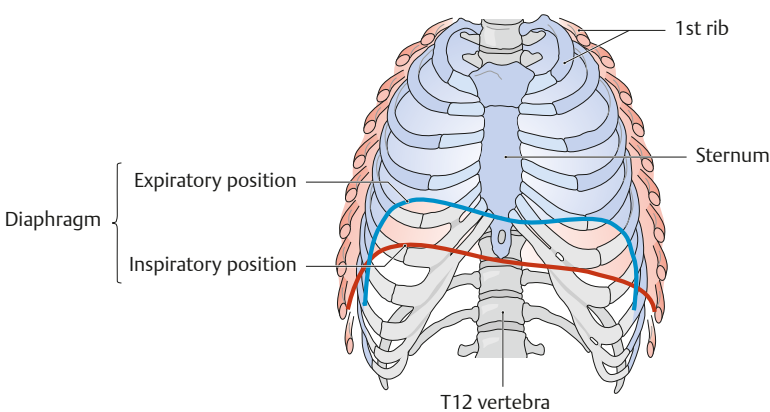


Fig. 10.16 Inspiration: Pleural cavity expansion

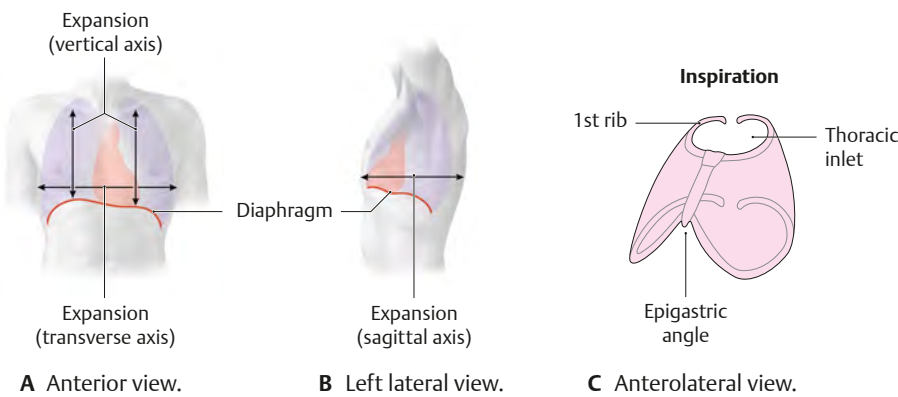


Fig. 10.18 Respiratory changes in lung volume

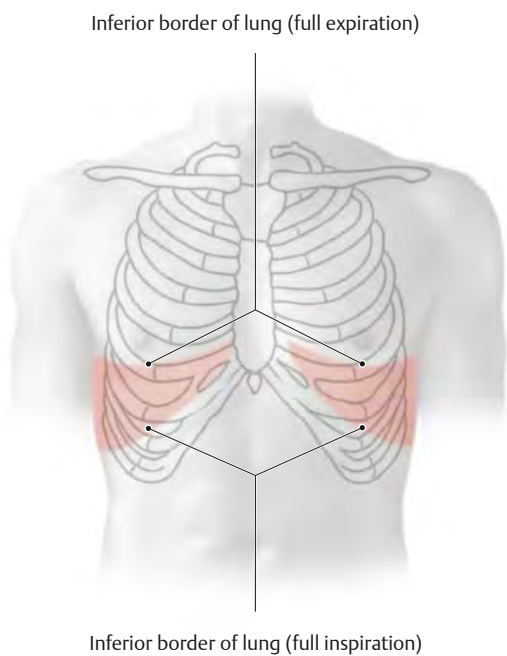


Fig. 10.17 Expiration: Pleural cavity contraction

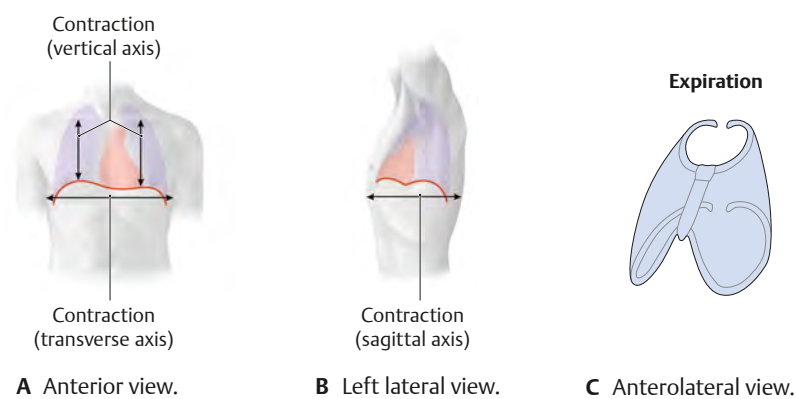
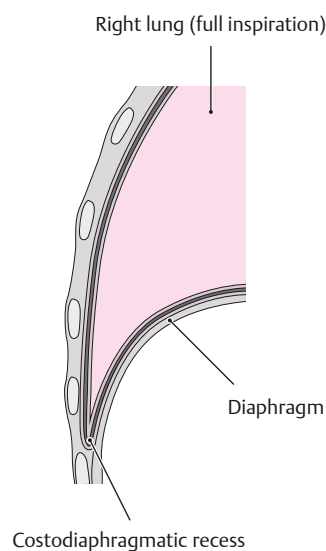
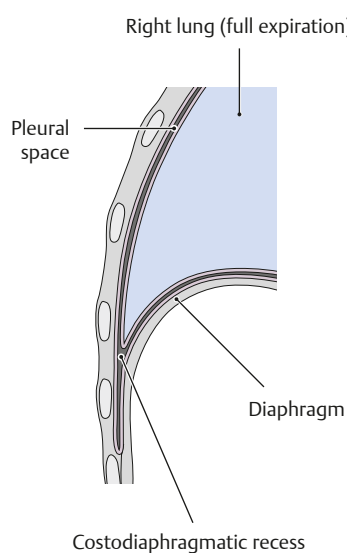
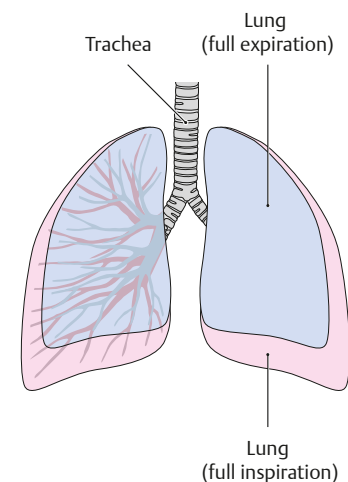


Fig. 10.19 Inspiration: Lung expansion**Fig. 10.20 Expiration: Lung contraction****Fig. 10.21 Movements of the lung and bronchial tree**

As the volume of the lung changes with the volume of the thoracic cavity, the entire bronchial tree moves within the lung. These structural movements are more pronounced in portions of the bronchial tree distant from the pulmonary hilum.

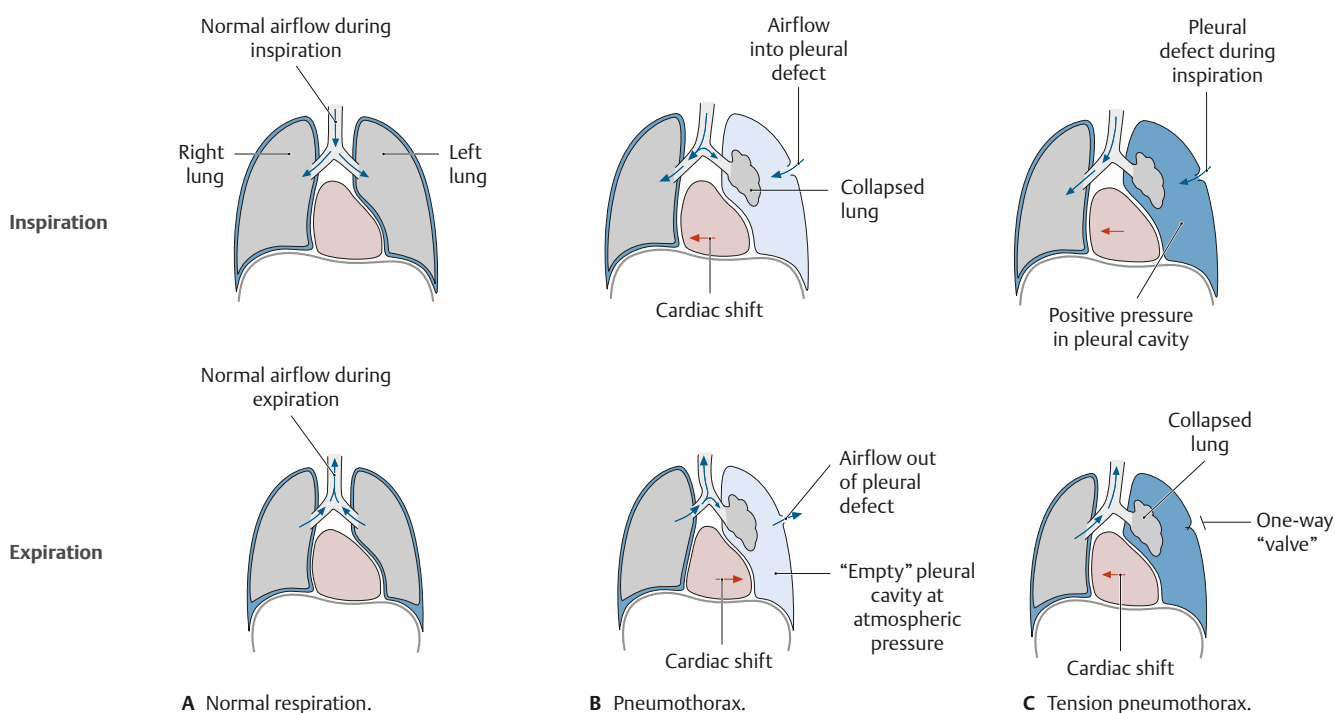


Clinical box 10.4

Pneumothorax

The pleural space is normally sealed from the outside environment. Injury to the parietal pleura, visceral pleura, or lung allows air to enter the pleural cavity (pneumothorax). The lung collapses due to its inherent elasticity, and the patient's ability to breathe is compromised. The uninjured lung continues to function under normal pressure variations, resulting in "mediastinal flutter": the mediastinum shifts toward the normal side during inspiration and returns to the midline during expiration. Tension (valve) pneumothorax

occurs when traumatically detached and displaced tissue covers the defect in the thoracic wall from the inside. This mobile flap allows air to enter, but not escape, the pleural cavity, causing a pressure buildup. The mediastinum shifts to the normal side, which may cause kinking of the great vessels and prevent the return of venous blood to the heart. Without treatment, tension pneumothorax is invariably fatal.

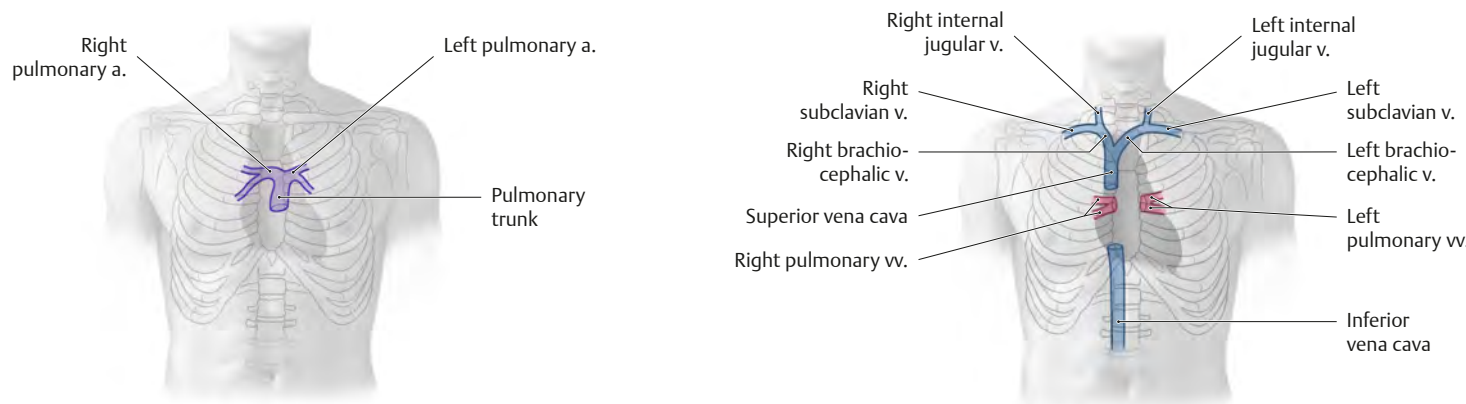


Pulmonary Arteries & Veins

The pulmonary trunk arises from the right ventricle and divides into a left and right pulmonary artery for each lung. The paired pulmonary veins open into the left atrium on each side. The pulmonary arteries

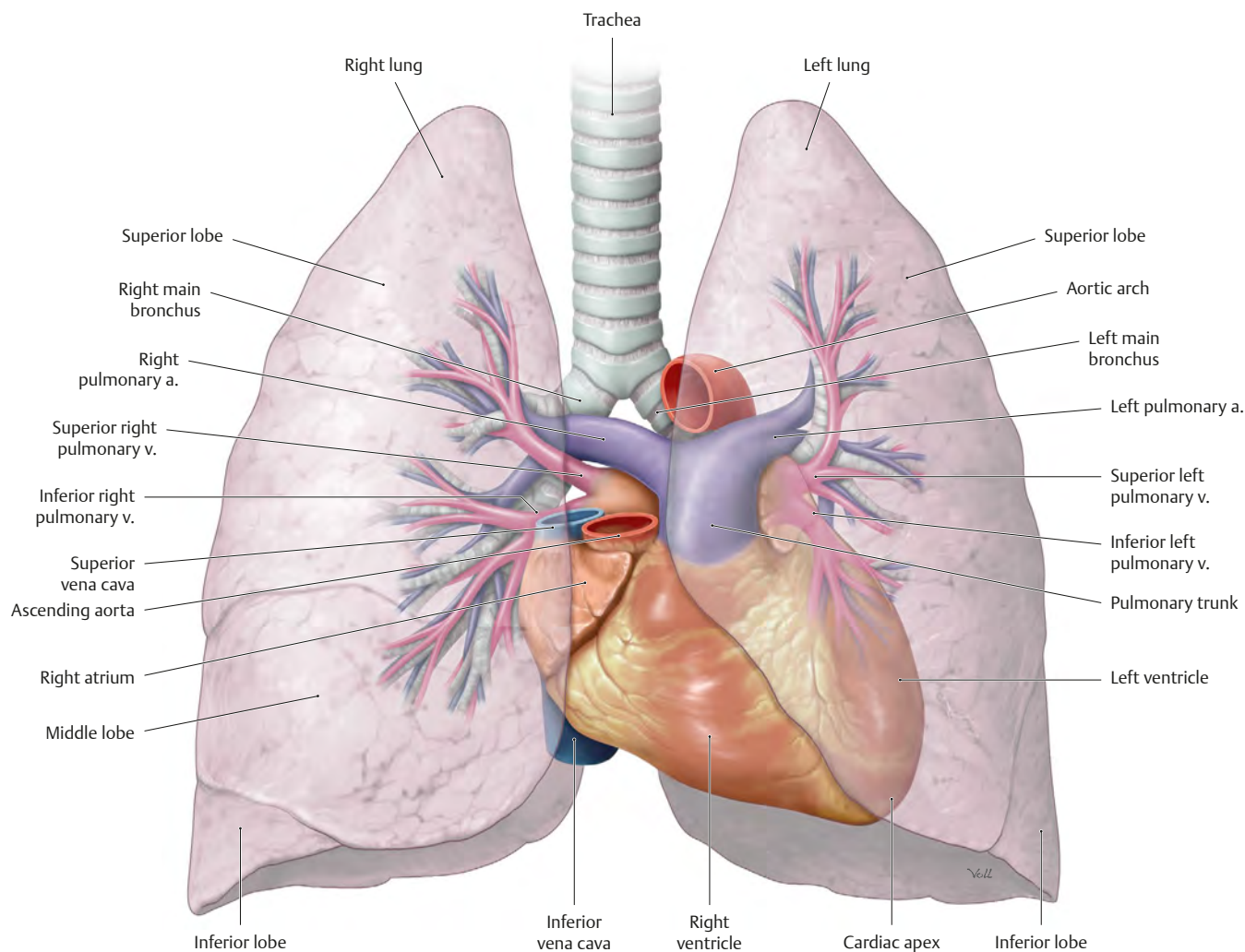
accompany and follow the branching of the bronchial tree, whereas the pulmonary veins do not, being located at the margins of the pulmonary lobules.

Fig. 10.22 Pulmonary arteries and veins
Anterior view.



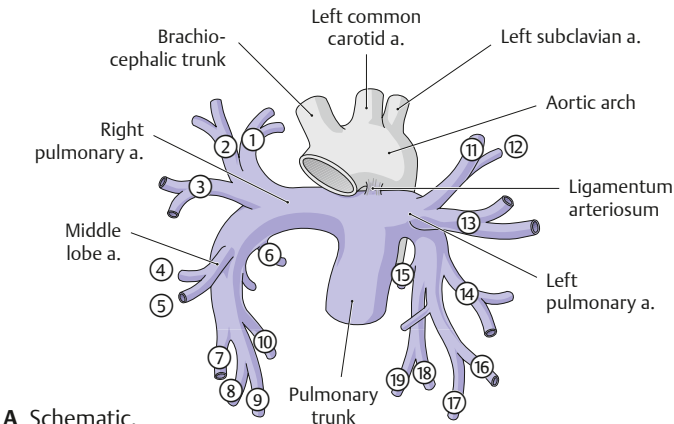
A Projection of pulmonary arteries on chest wall.

B Projection of pulmonary veins on chest wall.



C Distribution of the pulmonary arteries and veins, anterior view.

Fig. 10.23 Pulmonary arteries



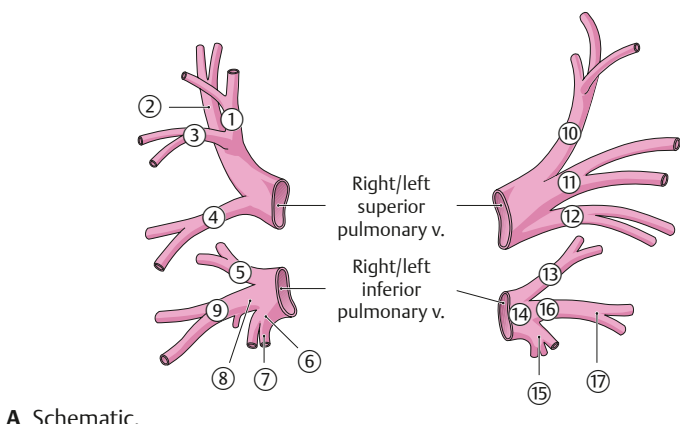
A Schematic.

Table 10.3		Pulmonary arteries and their branches	
Right pulmonary artery		Left pulmonary artery	
Superior lobe arteries			
①	Apical segmental a.		⑪
②	Posterior segmental a.		⑫
③	Anterior segmental a.		⑬
Middle lobe arteries			
④	Lateral segmental a.	Lingular a.	⑭
⑤	Medial segmental a.		
Inferior lobe arteries			
⑥	Superior segmental a.		⑮
⑦	Anterior basal segmental a.		⑯
⑧	Lateral basal segmental a.		⑰
⑨	Posterior basal segmental a.		⑱
⑩	Medial basal segmental a.		⑲

B Pulmonary arteriogram, arterial phase, anterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)



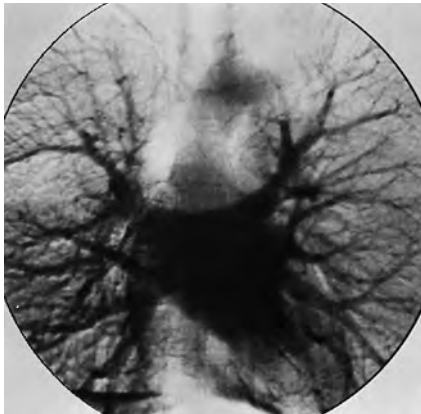
Fig. 10.24 Pulmonary veins



A Schematic.

Table 10.4 Pulmonary veins and their tributaries			
Right pulmonary vein		Left pulmonary vein	
Superior pulmonary veins			
①	Apical v.	Apicoposterior v.	⑩
②	Posterior v.		
③	Anterior v.	Anterior v.	⑪
④	Middle lobe v.	Lingular v.	⑫
Inferior pulmonary veins			
⑤	Superior v.		⑬
⑥	Common basal v.		⑭
⑦	Inferior basal v.		⑮
⑧	Superior basal v.		⑯
⑨	Anterior basal v.		⑰

B Pulmonary arteriogram, venous phase, anterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)



Clinical box 10.5

Pulmonary embolism

Potentially life-threatening pulmonary embolism occurs when blood clots migrate through the venous system and become lodged in one of the arteries supplying the lungs. Symptoms include dyspnea (difficulty breathing) and tachycardia (increased heart rate). Most pulmonary emboli

originate from stagnant blood in the veins of the lower limb and pelvis (venous thromboemboli). Causes include immobilization, disordered blood coagulation, and trauma. *Note:* A thromboembolus is a thrombus (blood clot) that has migrated (embolized).

Neurovasculature of the Tracheobronchial Tree

Fig. 10.25 Pulmonary vasculature

The pulmonary system is responsible for gaseous exchange within the lung. Pulmonary arteries (shown in blue) carry *deoxygenated* blood and follow the bronchial tree. The pulmonary vein and its tributaries (red) is the only vein in the body carrying *oxygenated* blood, which it receives from the alveolar capillaries at the periphery of the lobule.

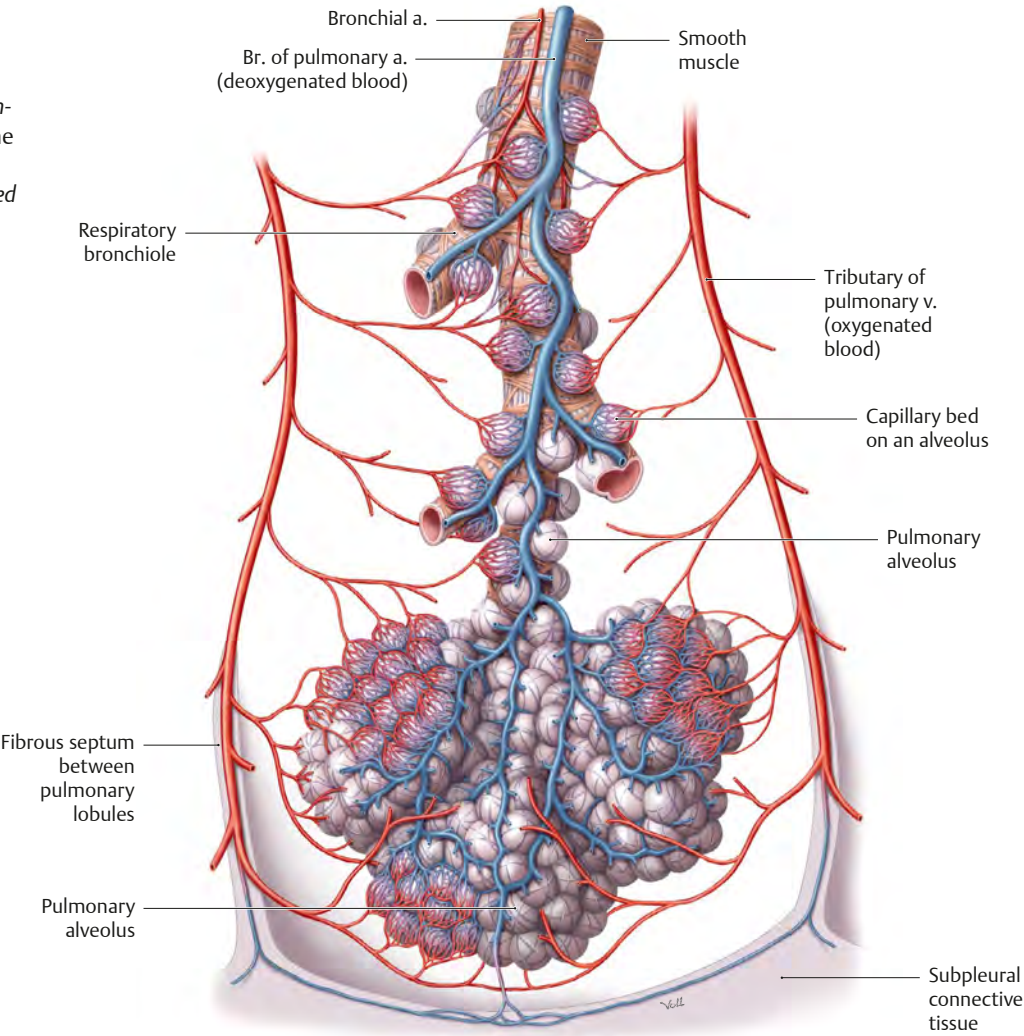


Fig. 10.26 Arteries of the tracheobronchial tree

The bronchial tree receives its nutrients via the bronchial arteries, found in the adventitia of the airways. Typically, there are one to three bronchial arteries arising directly from the aorta. Origin from a posterior intercostal artery may also occur.

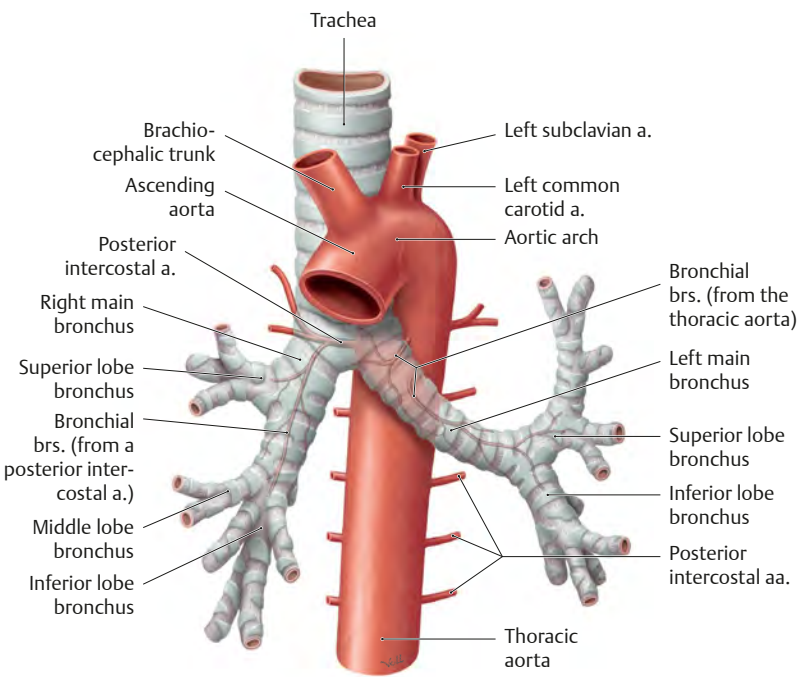


Fig. 10.27 Veins of the tracheobronchial tree

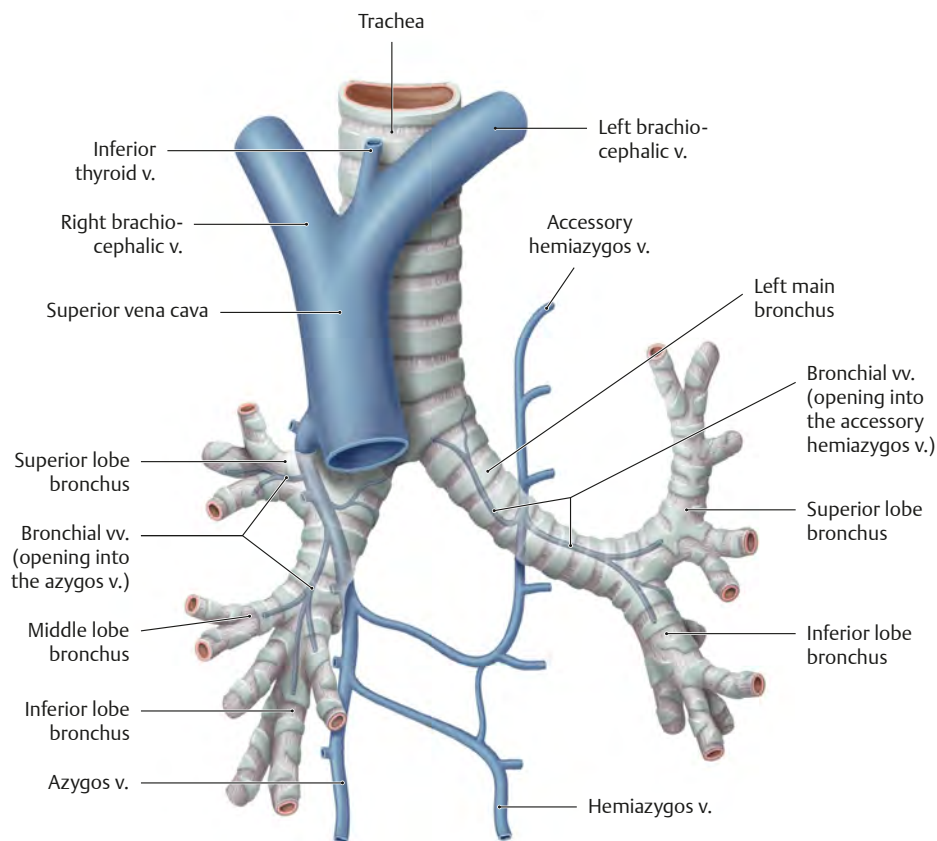
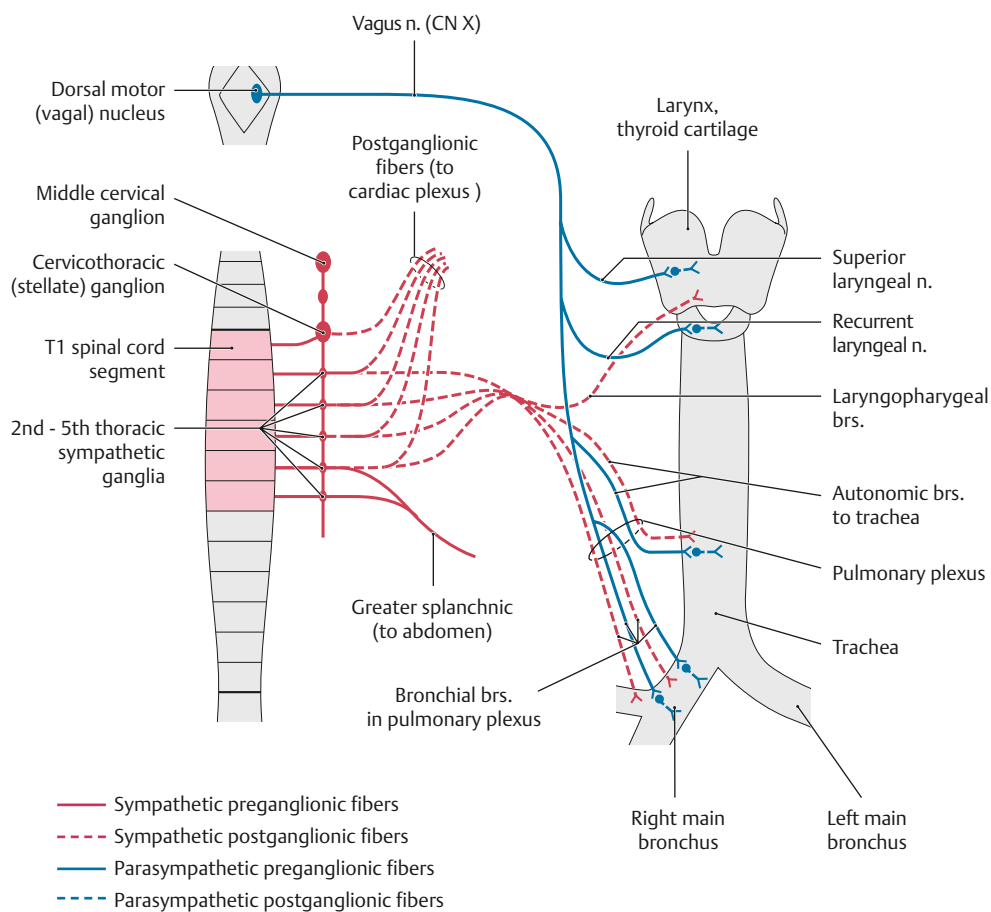


Fig. 10.28 Autonomic innervation of the tracheobronchial tree

Sympathetic innervation (red);
parasympathetic innervation (blue).



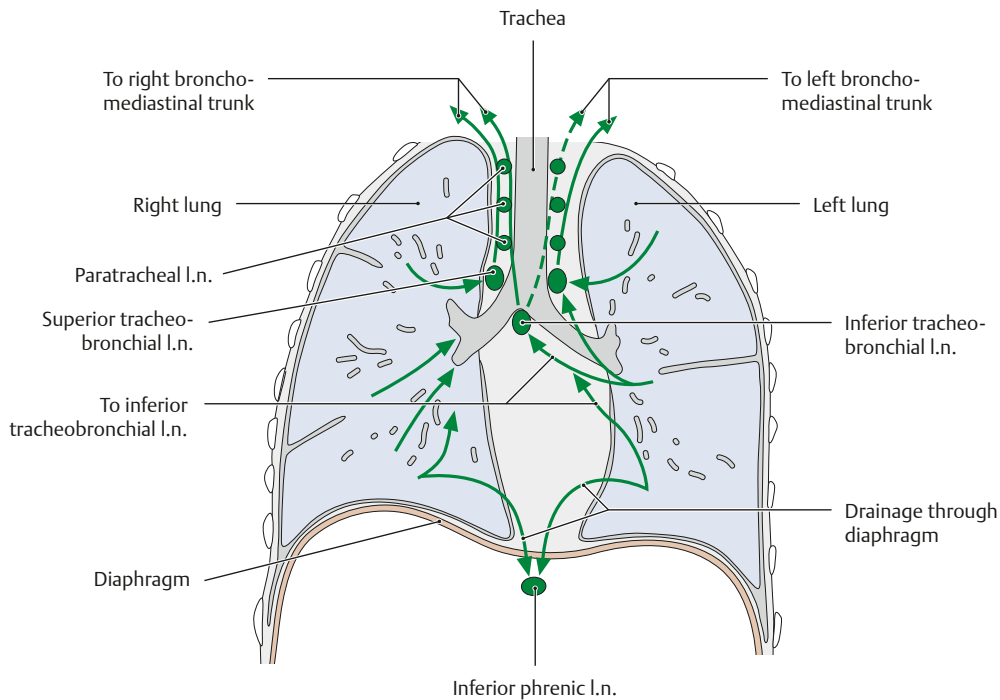
Lymphatics of the Pleural Cavity

The lungs and bronchi are drained by two lymphatic drainage systems. The peribronchial network follows the bronchial tree, draining lymph

from the bronchi and most of the lungs. The subpleural network collects lymph from the peripheral lung and visceral pleura.

Fig. 10.29 Lymphatic drainage of the pleural cavity and thoracic wall

A Peribronchial network, coronal section, anterior view. (Intra)pulmonary nodes along the bronchial tree drain lymph from the lungs into the bronchopulmonary (hilar) nodes. Lymph then passes sequentially through the inferior and superior tracheobronchial nodes, paratracheal nodes, bronchomediastinal trunk, and finally to the right lymphatic or thoracic duct. *Note:* Significant amounts of lymph from the left lower lobe drain to the right superior tracheobronchial nodes.



B Subpleural and thoracic wall networks, transverse section, superior view.

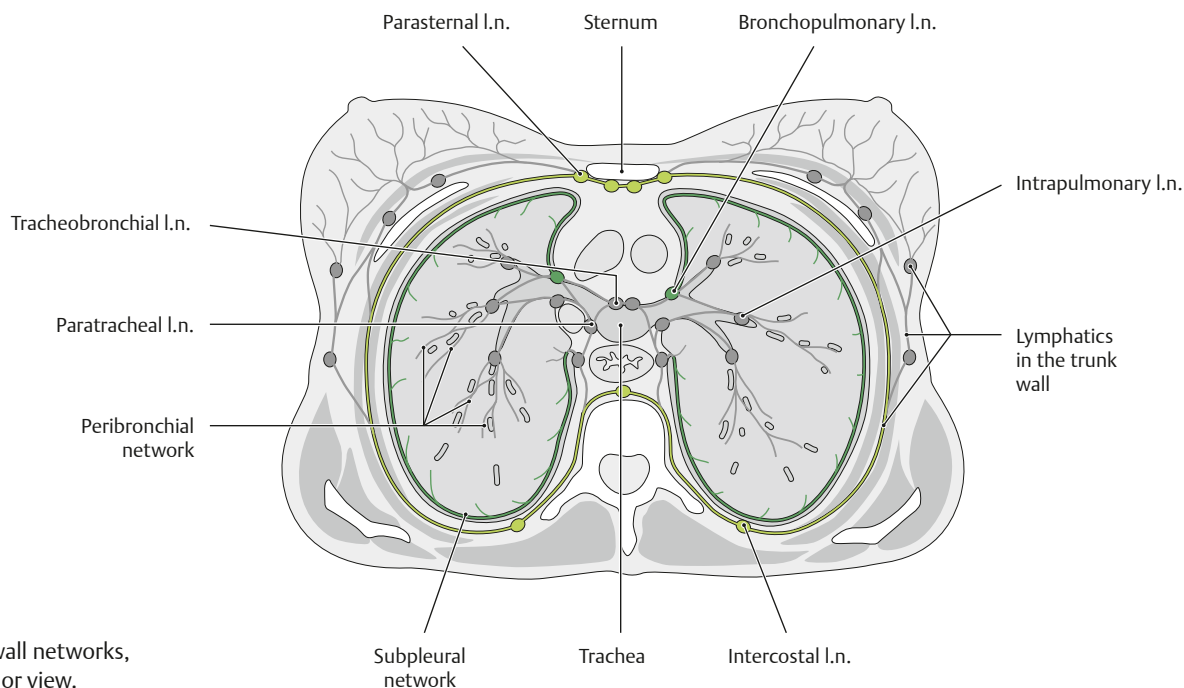
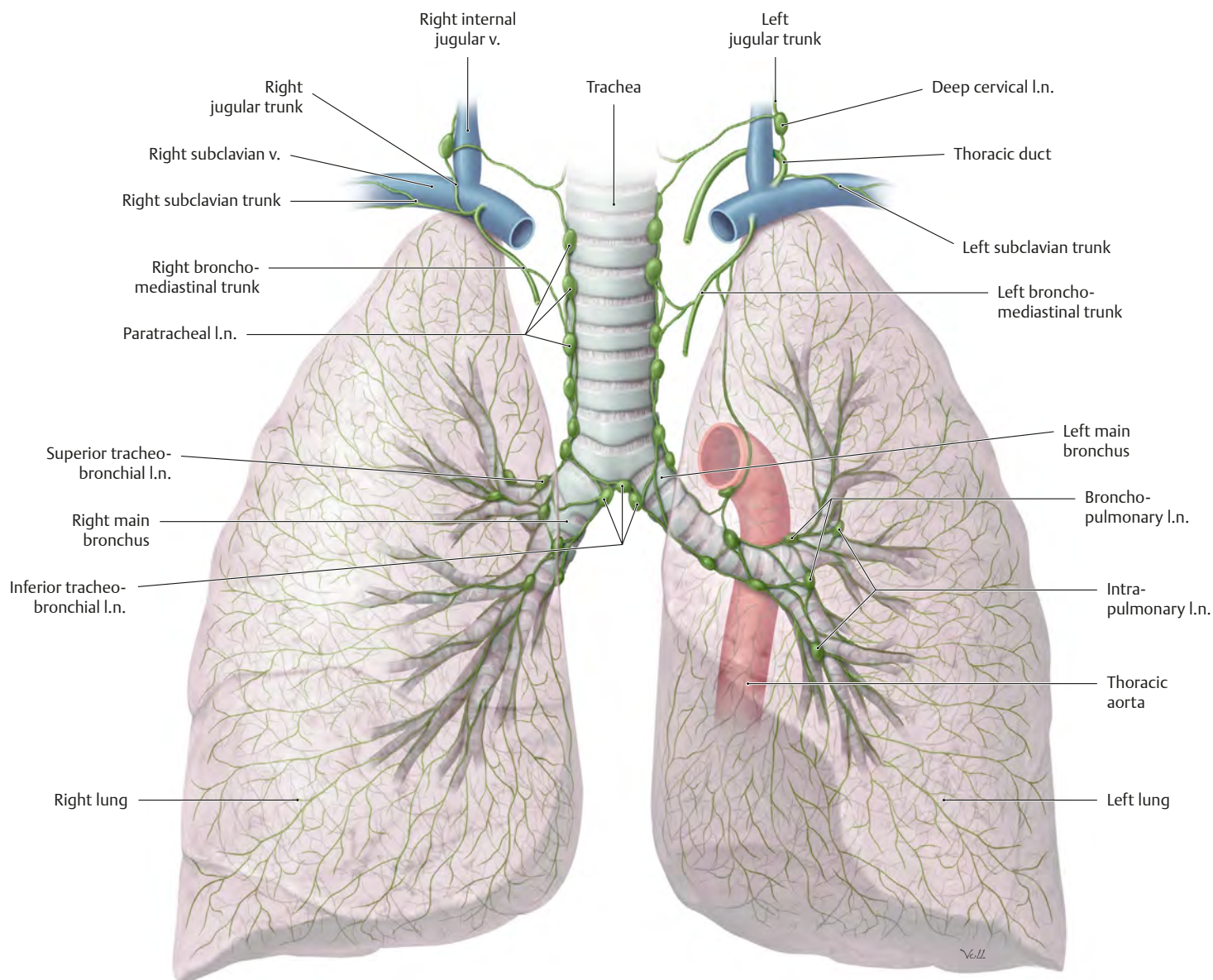


Fig. 10.30 Lymph nodes of the pleural cavity

Anterior view of pulmonary nodes.

**Clinical box 10.6****Carcinoma of the Lung**

Carcinoma of the lung accounts for $\approx 20\%$ of all cancers and is mainly caused by cigarette smoking. It arises first in the lining of the bronchi and metastasizes quickly to bronchopulmonary lymph nodes and subsequently to other node groups, including supraclavicular nodes. It can also spread via

the blood to the lungs, brain, bone, and suprarenal glands. Lung cancer can invade adjacent structures such as the phrenic nerve, resulting in paralysis of a hemidiaphragm, or the recurrent laryngeal nerve, resulting in hoarseness due to paralysis of the vocal cord.

11 Sectional & Radiographic Anatomy

Sectional Anatomy of the Thorax

Fig. 11.1 Transverse section through the thoracic inlet region of the thorax
Inferior view.

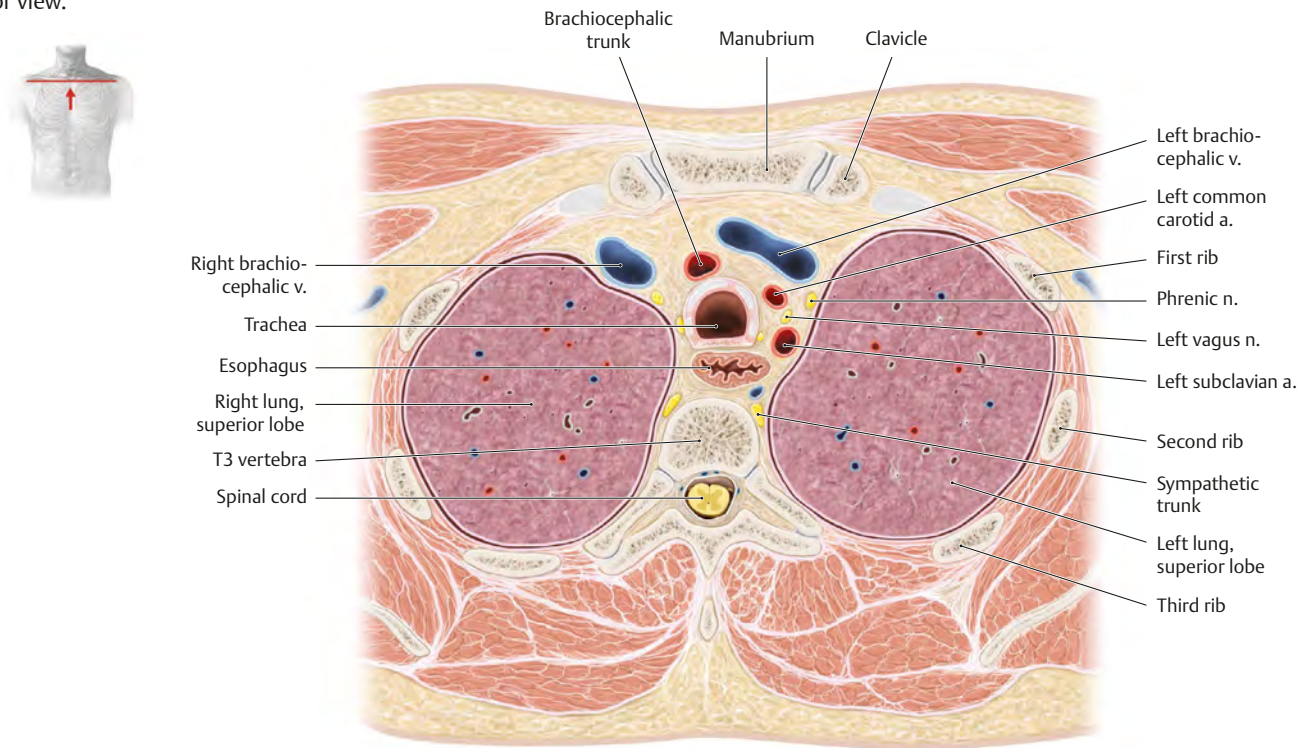
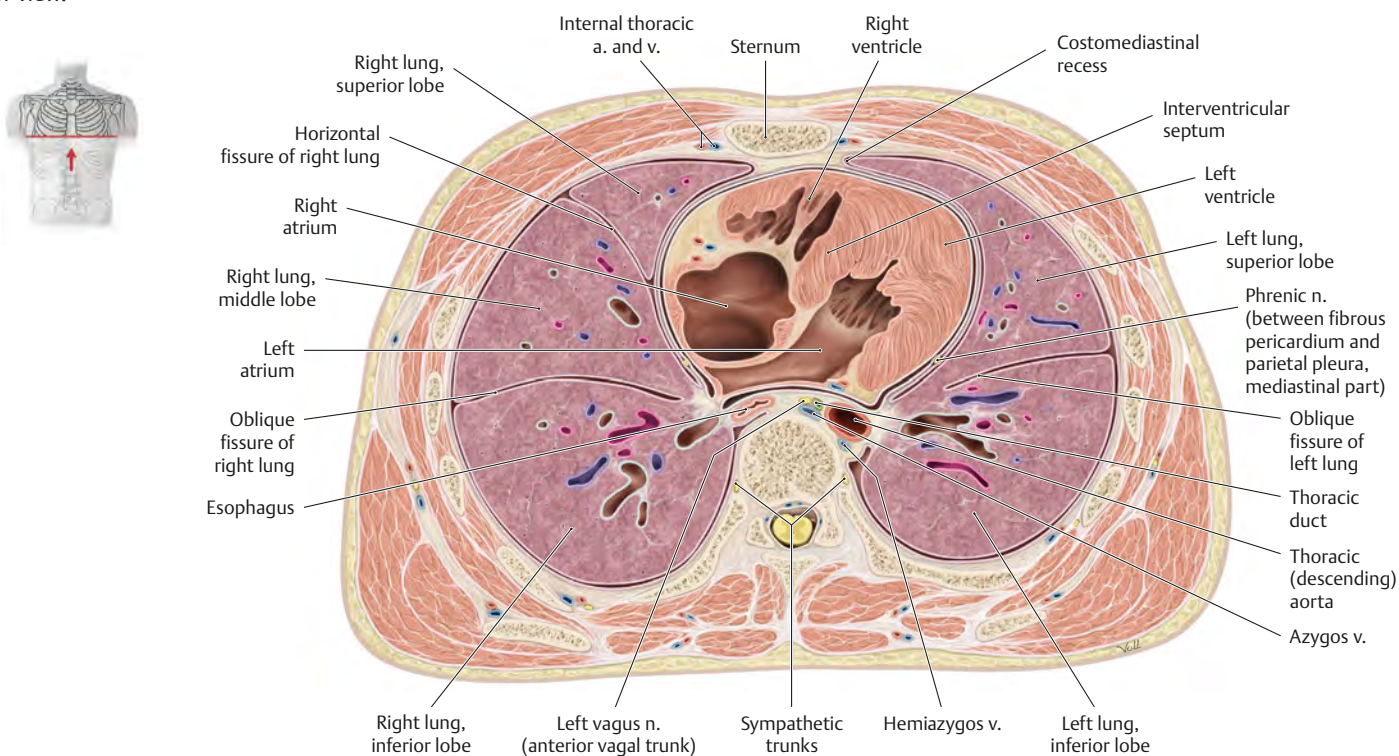


Fig. 11.2 Transverse section through the mid region of the thorax
Inferior view.



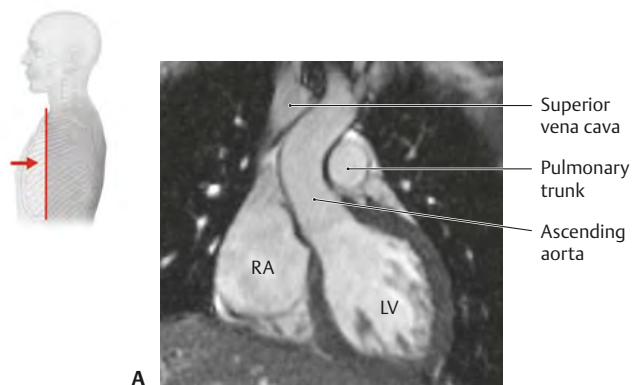


Fig. 11.3 Coronal section through heart and similar MRI

- A** Image displays left ventricular outflow tract (LVOT) during diastole.
- B** Corresponding coronal (frontal) anatomical cross section of the heart, anterior view.

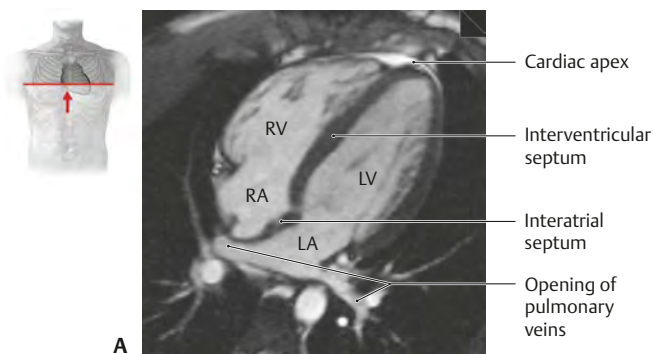


Fig. 11.4 Transverse section through heart and similar MRI

- A** Image displays the atrioventricular connections of both the right and left sides of the heart during diastole (four-chamber view).
- B** Corresponding transverse anatomical cross section of the heart, inferior view.

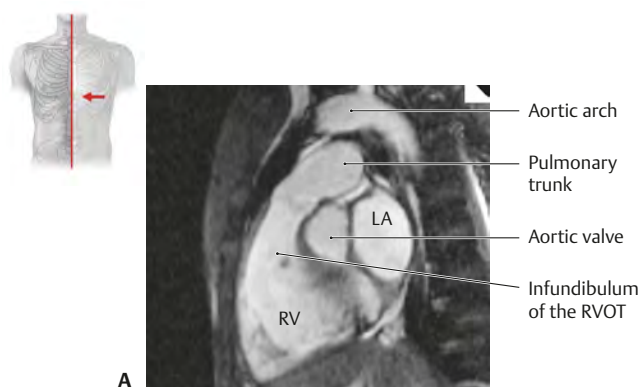
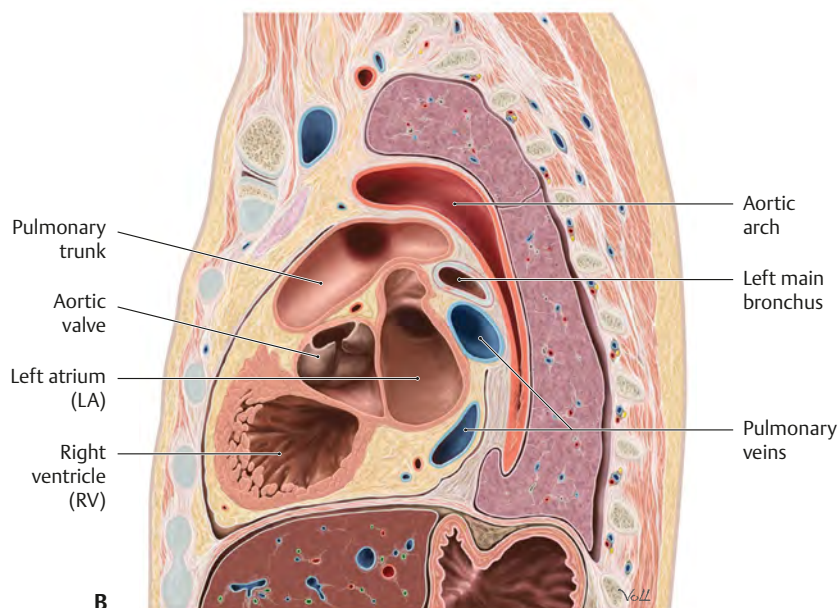


Fig. 11.5 Sagittal section of the heart and similar MRI

- A** Image displays the right ventricular outflow tract (RVOT) during diastole.
- B** Corresponding sagittal anatomical cross section of the heart, viewed from the left side.



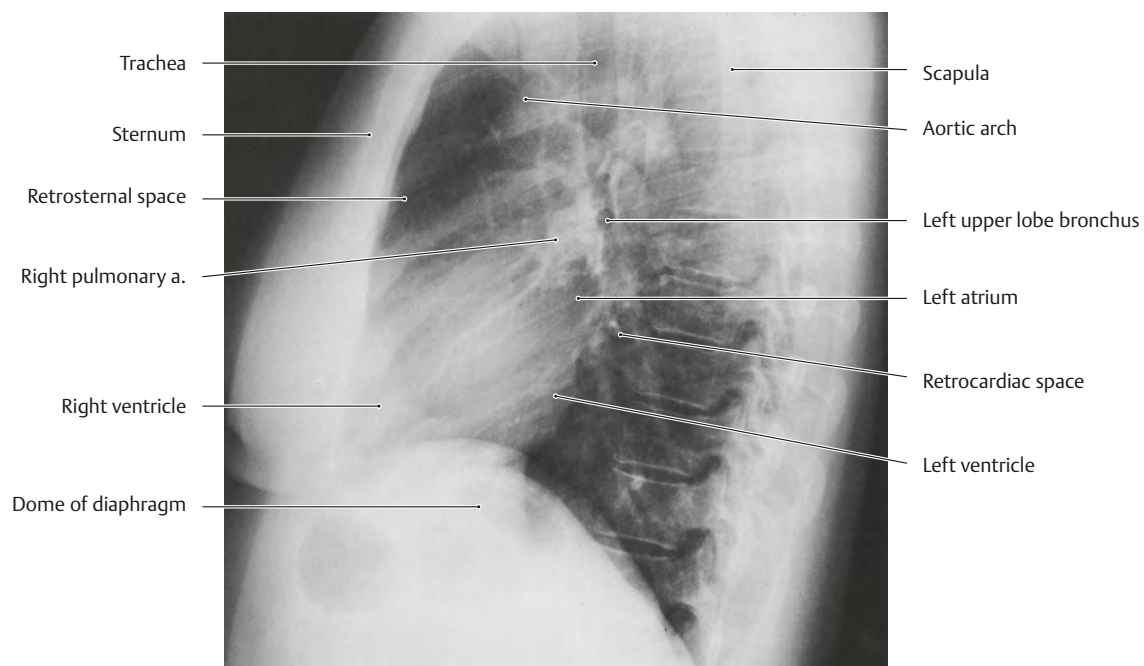
Radiographic Anatomy of the Thorax (I)

Fig. 11.6

(Reproduced from Lange S. Radiologische Diagnostik der Thoraxerkrankungen, 4th ed. Stuttgart: Thieme; 2010.)



A Posterior-anterior (PA) chest radiograph. Anterior view.



B Left lateral chest radiograph.

Fig. 11.7 Left bronchogram

Anteroposterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

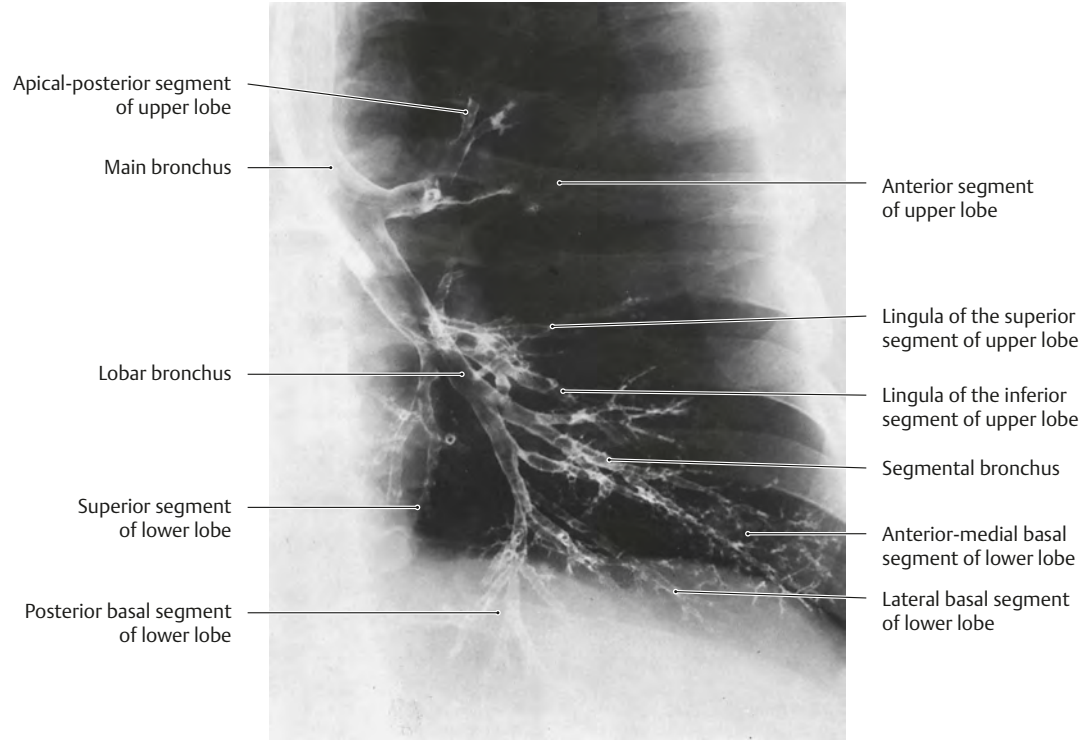
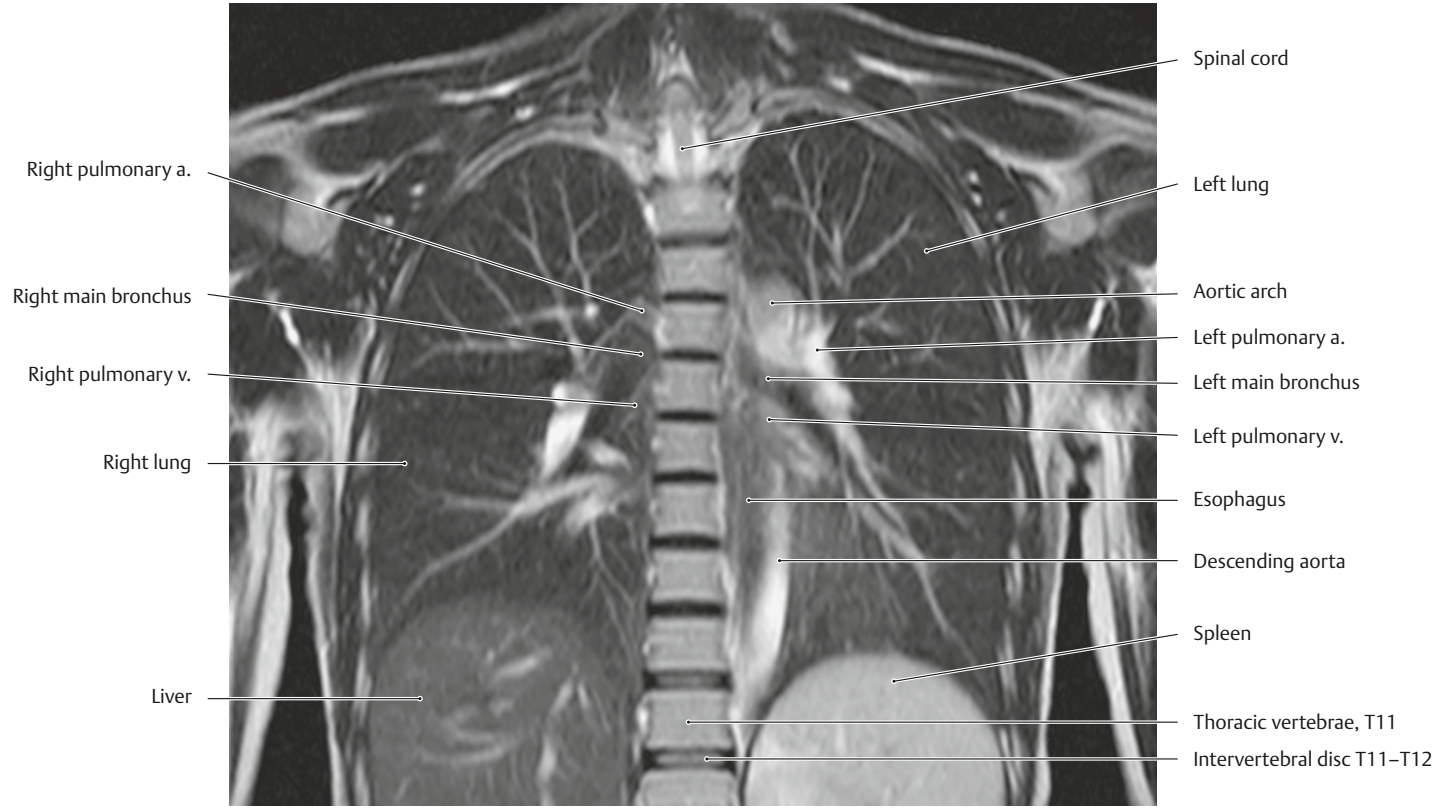


Fig. 11.8 MRI of the thorax

Coronal view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 3rd ed. New York, NY: Thieme; 2007.)



Radiographic Anatomy of the Thorax (II)

Fig. 11.9 Selective coronary angiography of the left coronary artery in a right anterior oblique position

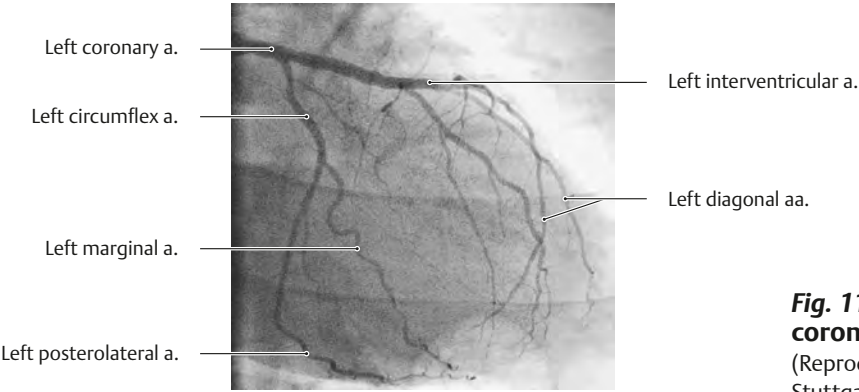


Fig. 11.10 Selective coronary angiography of the right coronary artery in a left anterior oblique projection
(Reproduced from Thelen M. et al. Bildgebene Kardiagnostik. Stuttgart: Thieme; 2007.)

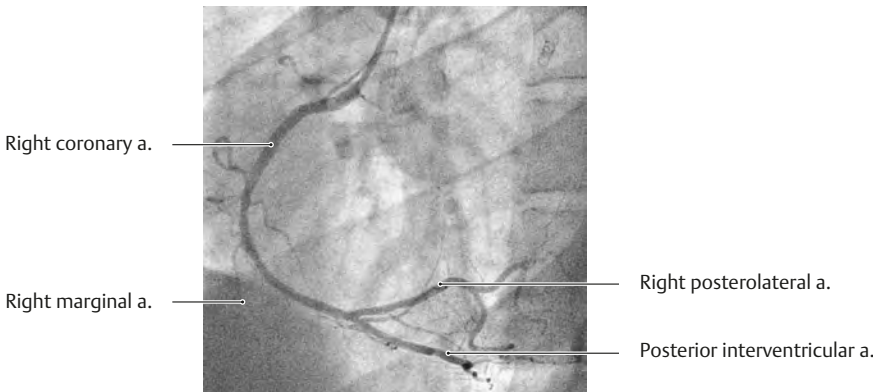
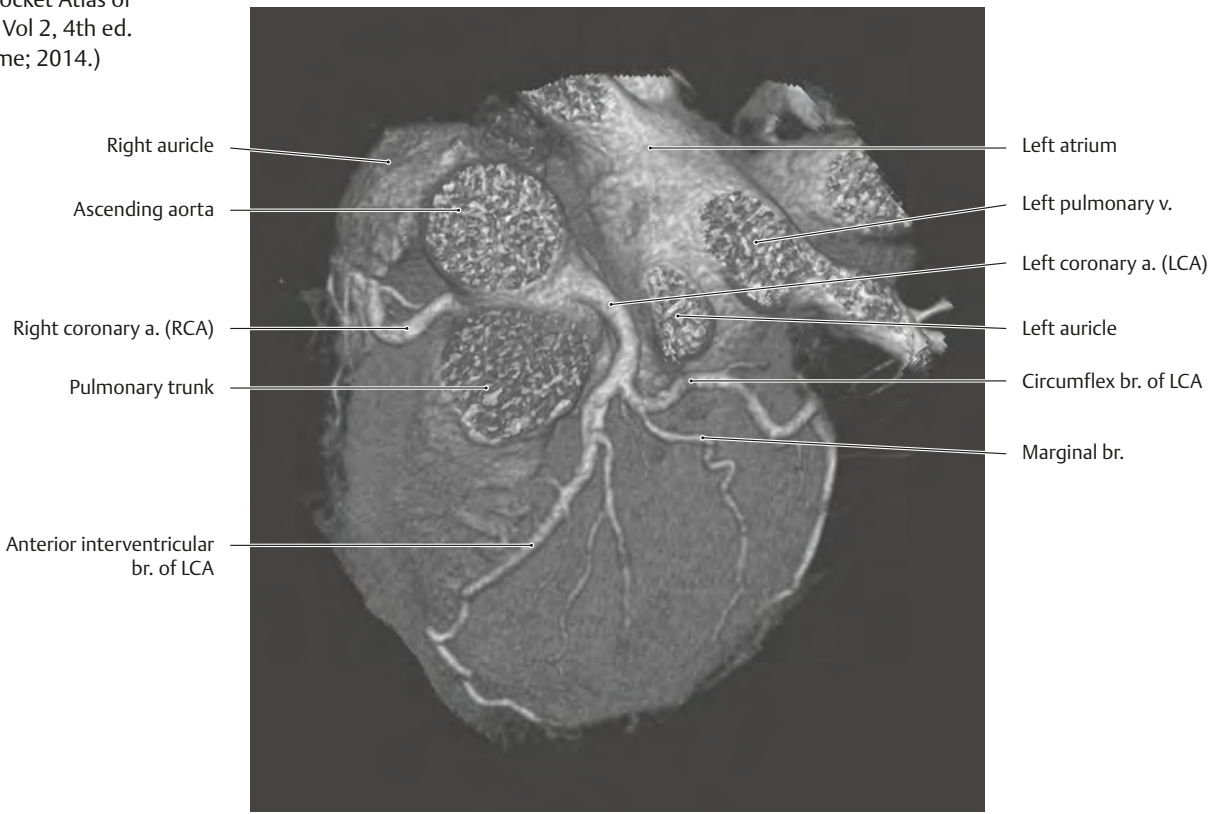
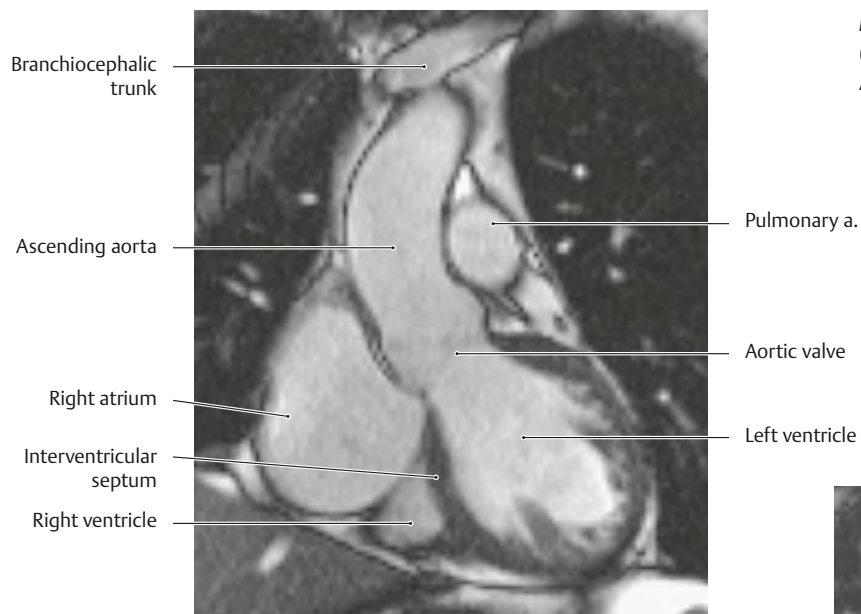
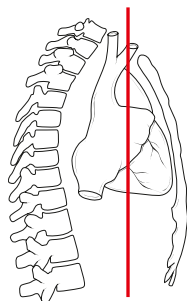


Fig. 11.11 CT of the heart
CT angiography. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)





A Left ventricular outflow tract.



B Two chamber view of right ventricle.

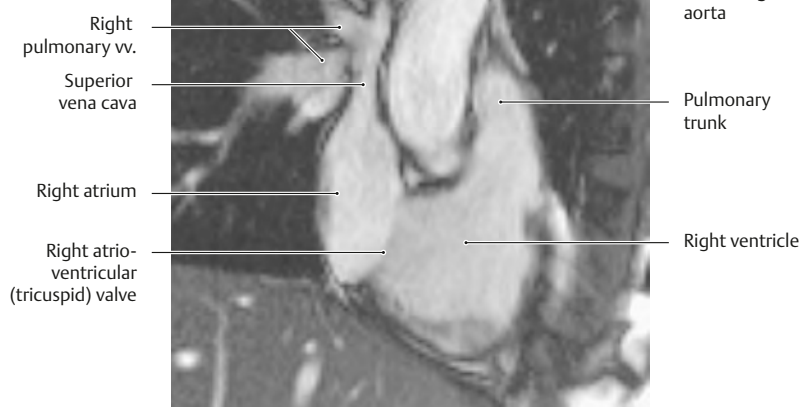


Fig. 11.12 MRI of the heart

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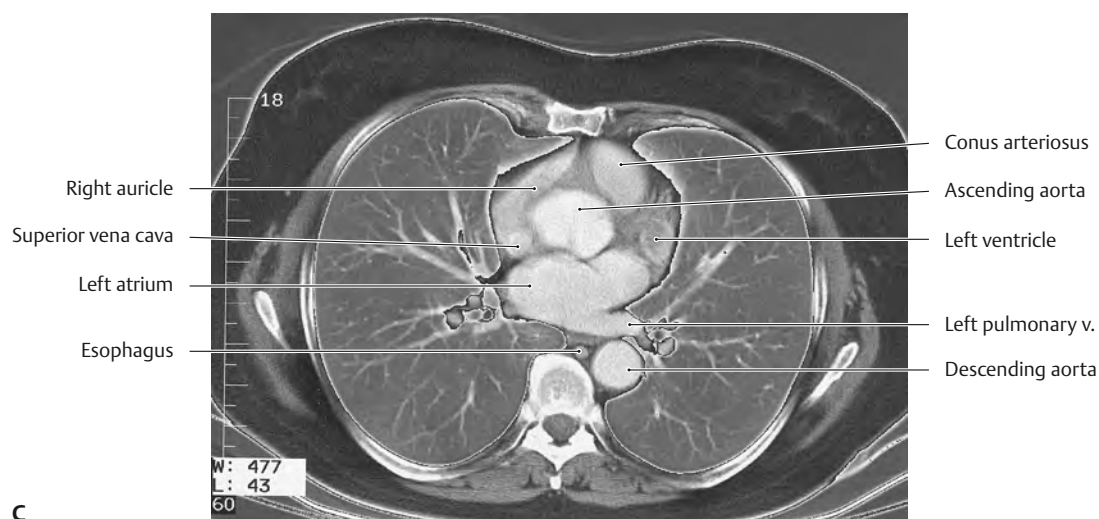
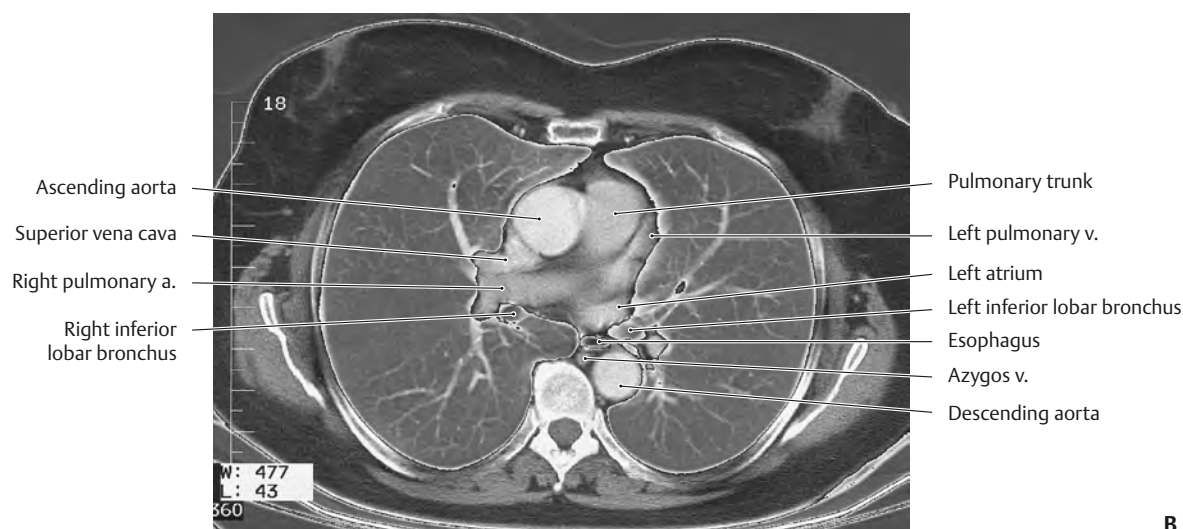
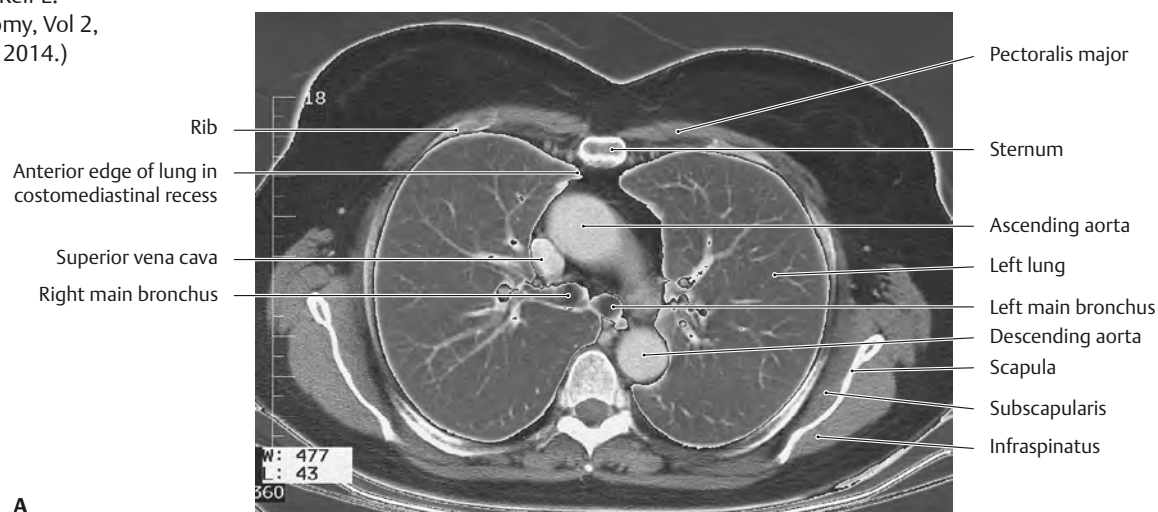
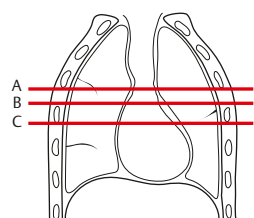
Fig. 11.13 Aortic arch angiogram

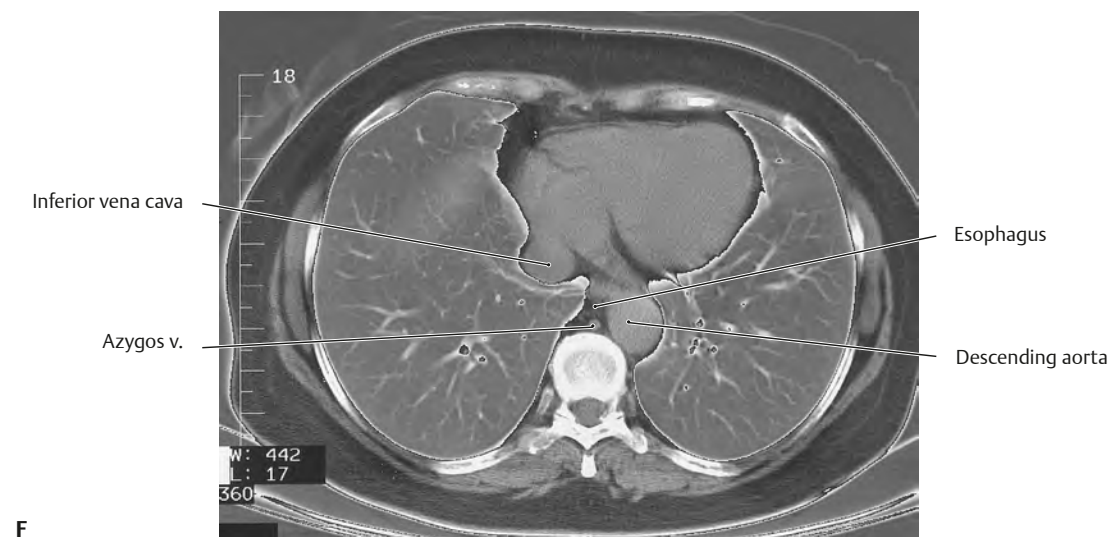
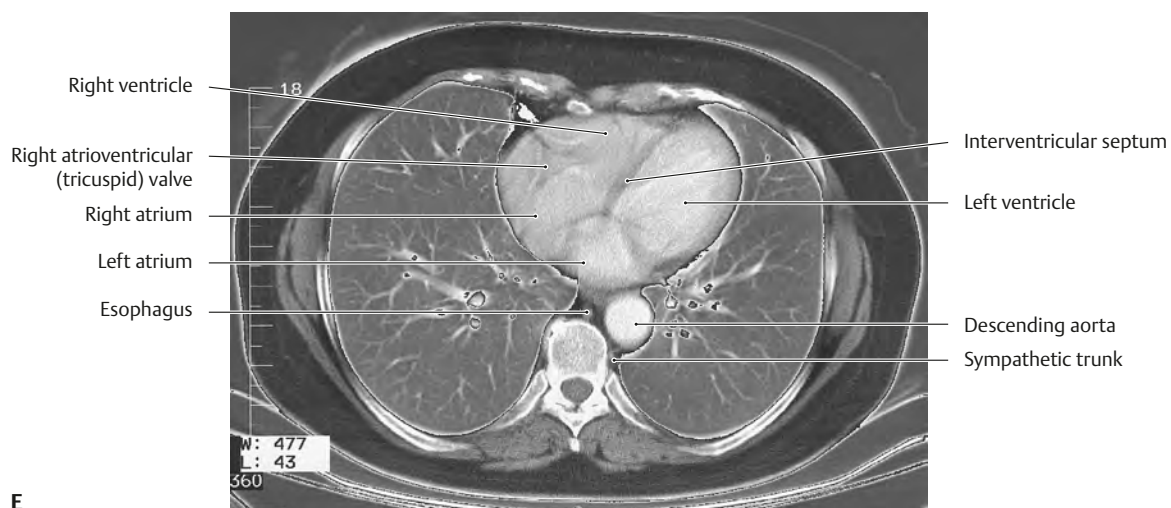
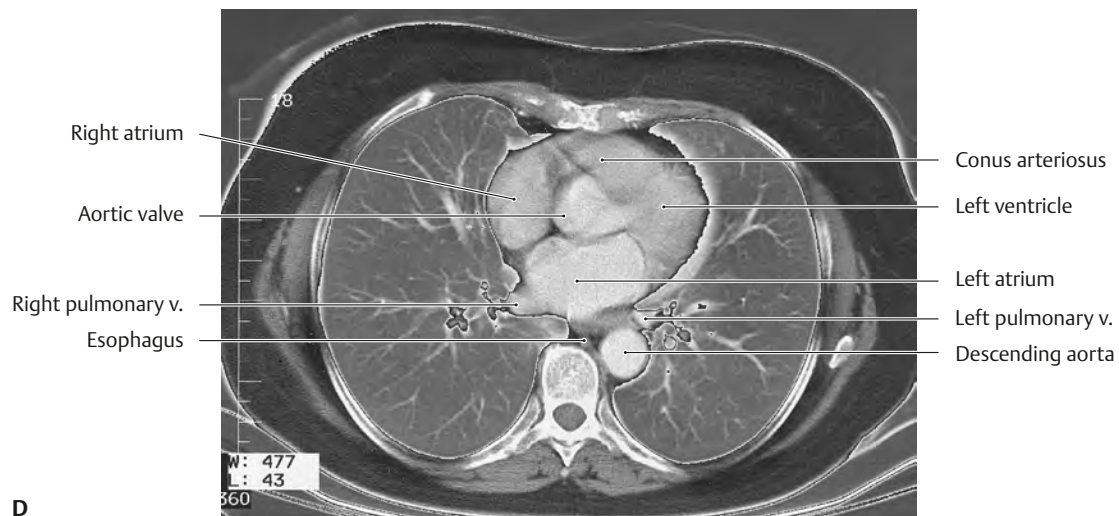
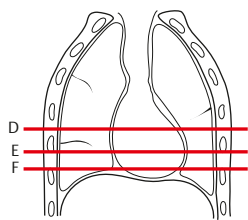
Left lateral view.

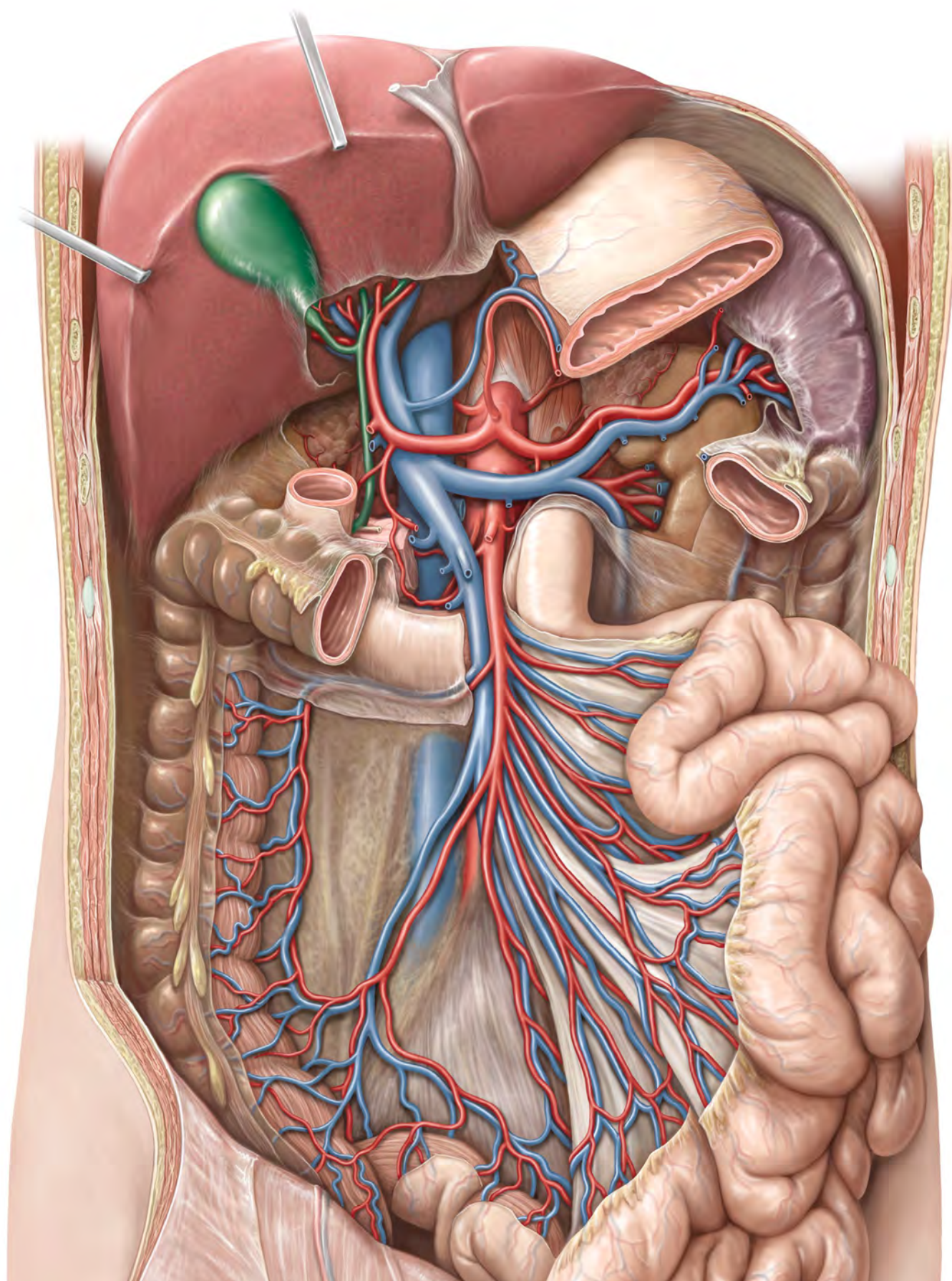


Fig. 11.14 CT of the thorax

(Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)







Abdomen

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12 Surface Anatomy

Surface Anatomy

Fig. 12.1 Palpable structures of the abdomen and pelvis
Anterior view. See pp. 2–3 for structures of the back.

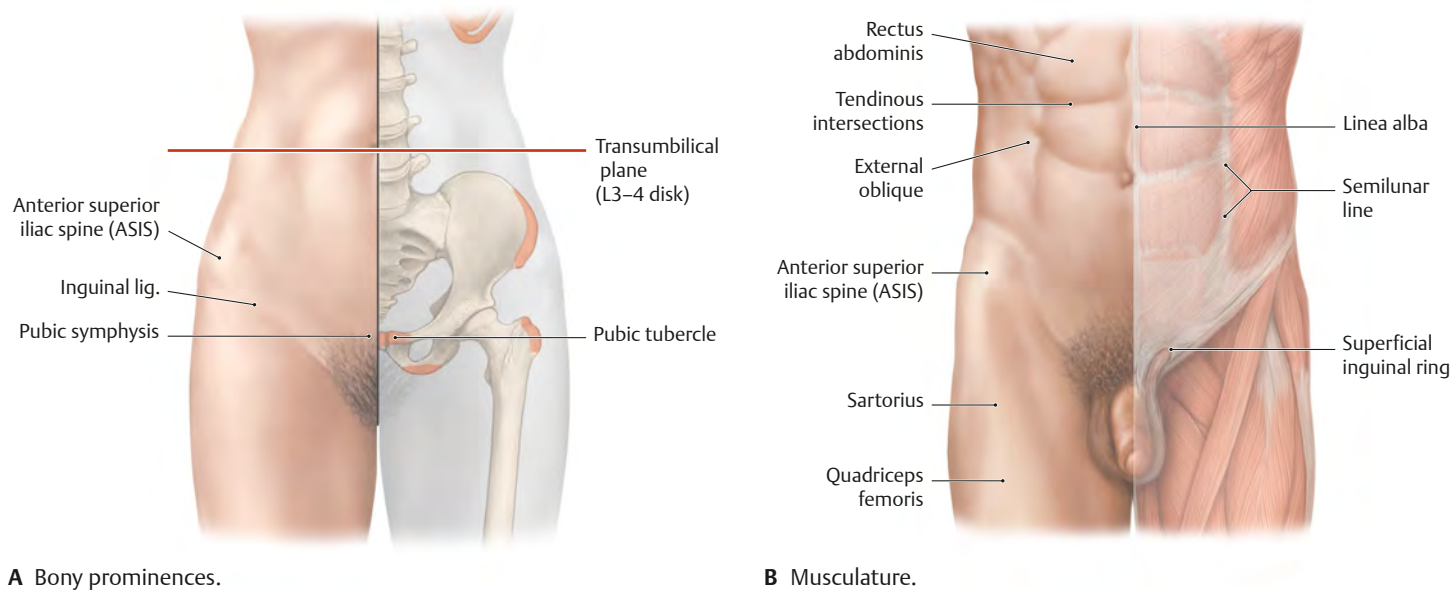


Fig. 12.2 Quadrants and layers of the abdominopelvic cavity
Anterior view. The location of the organs of the abdomen and pelvis can be described by quadrant and layer.

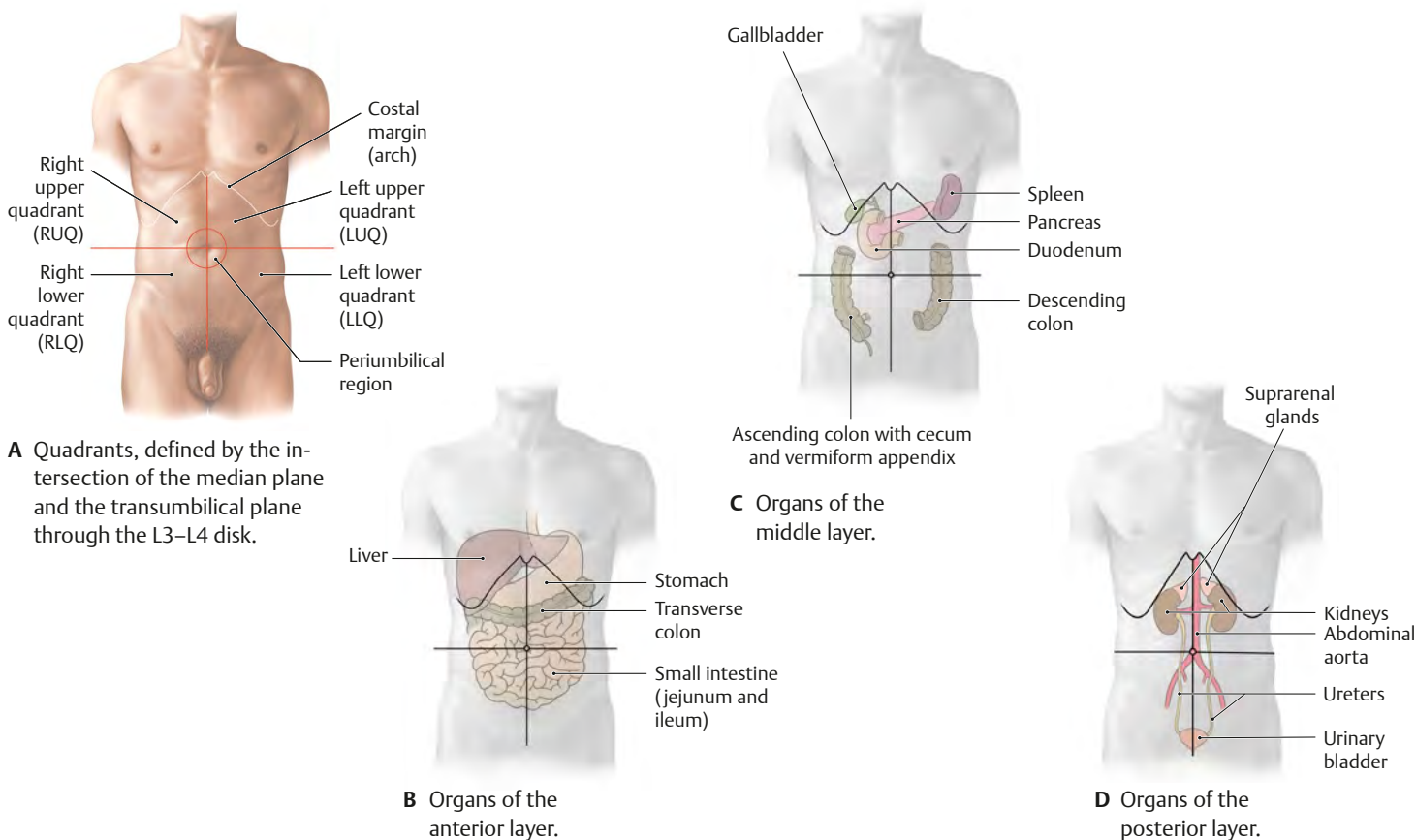
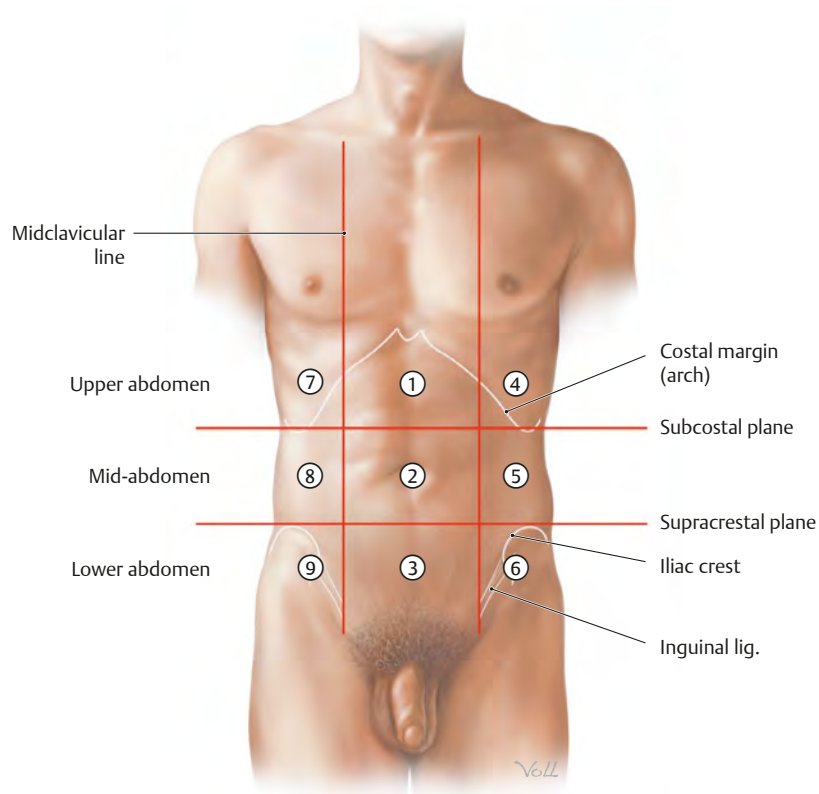
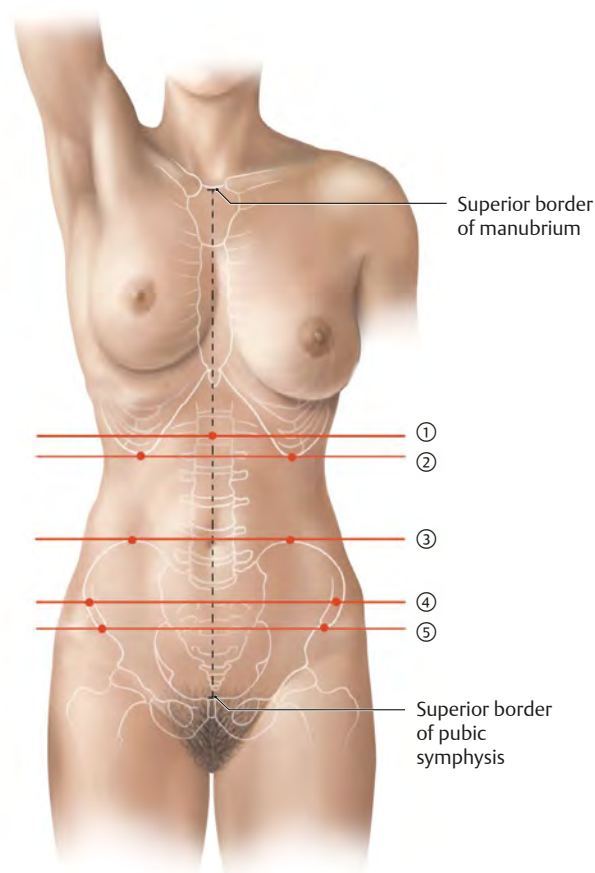


Table 12.1 Transverse planes through the abdomen

① Transpyloric plane	Transverse plane midway between the superior borders of the pubic symphysis and the manubrium
② Subcostal plane	Plane at the lowest level of the costal margin (the inferior margin of the tenth costal cartilage)
③ Supracrestal plane	Plane passing through the summits of the iliac crests
④ Transtubercular plane	Plane at the level of the iliac tubercles (the iliac tubercle lies ~5 cm posterolateral to the anterior superior iliac spine)
⑤ Interspinous plane	Plane at the level of the anterior superior iliac spines

**Table 12.2** Regions of the abdomen

① Epigastric region
② Umbilical region
③ Pubic region
④ Left hypochondriac region
⑤ Left lateral (lumbar) region
⑥ Left inguinal region
⑦ Right hypochondriac region
⑧ Right lateral (lumbar) region
⑨ Right inguinal region

13 Abdominal Wall

Bony Framework for the Abdominal Wall

Fig. 13.1 Bony framework of the abdomen
Anterior view. These bones are the site of attachment for the muscles and ligaments of the anterolateral abdominal wall and form a bony cage that protects certain abdominal organs.

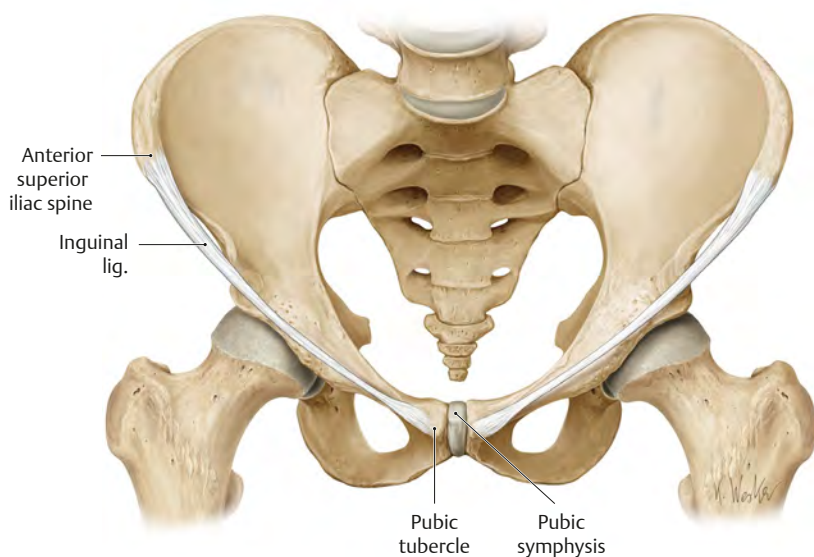
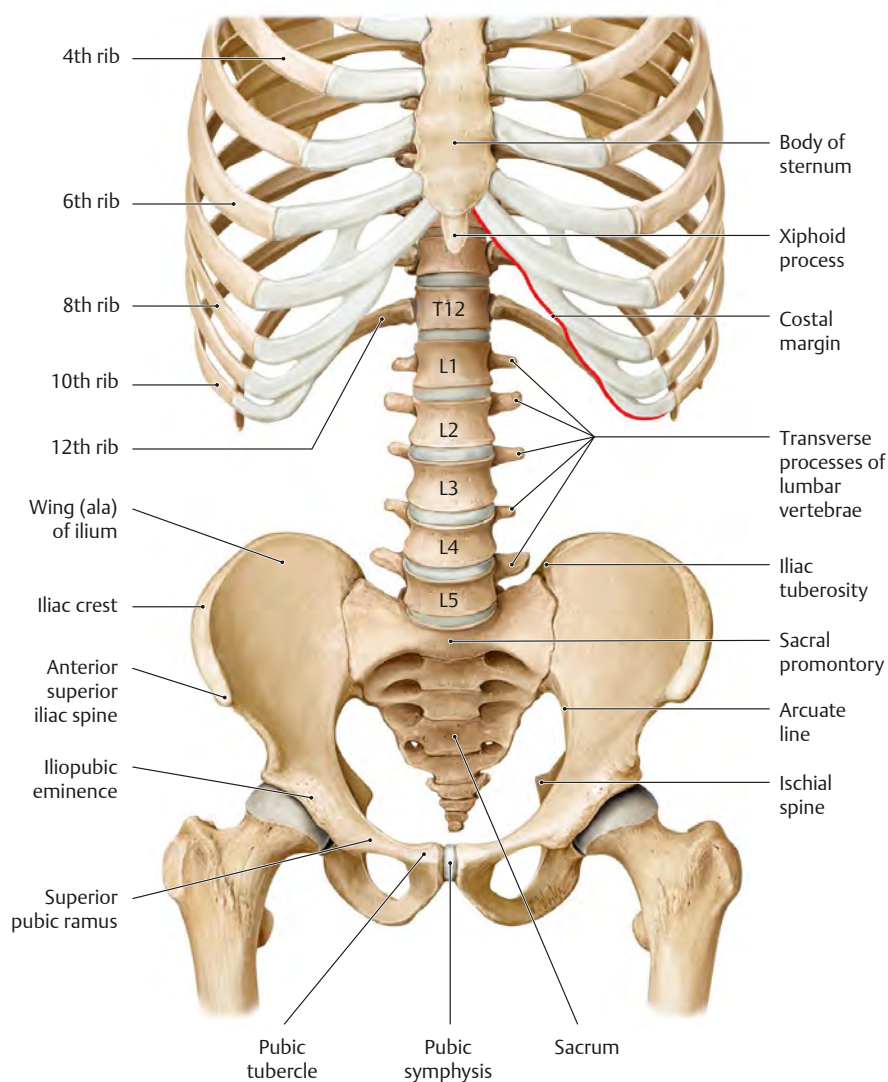
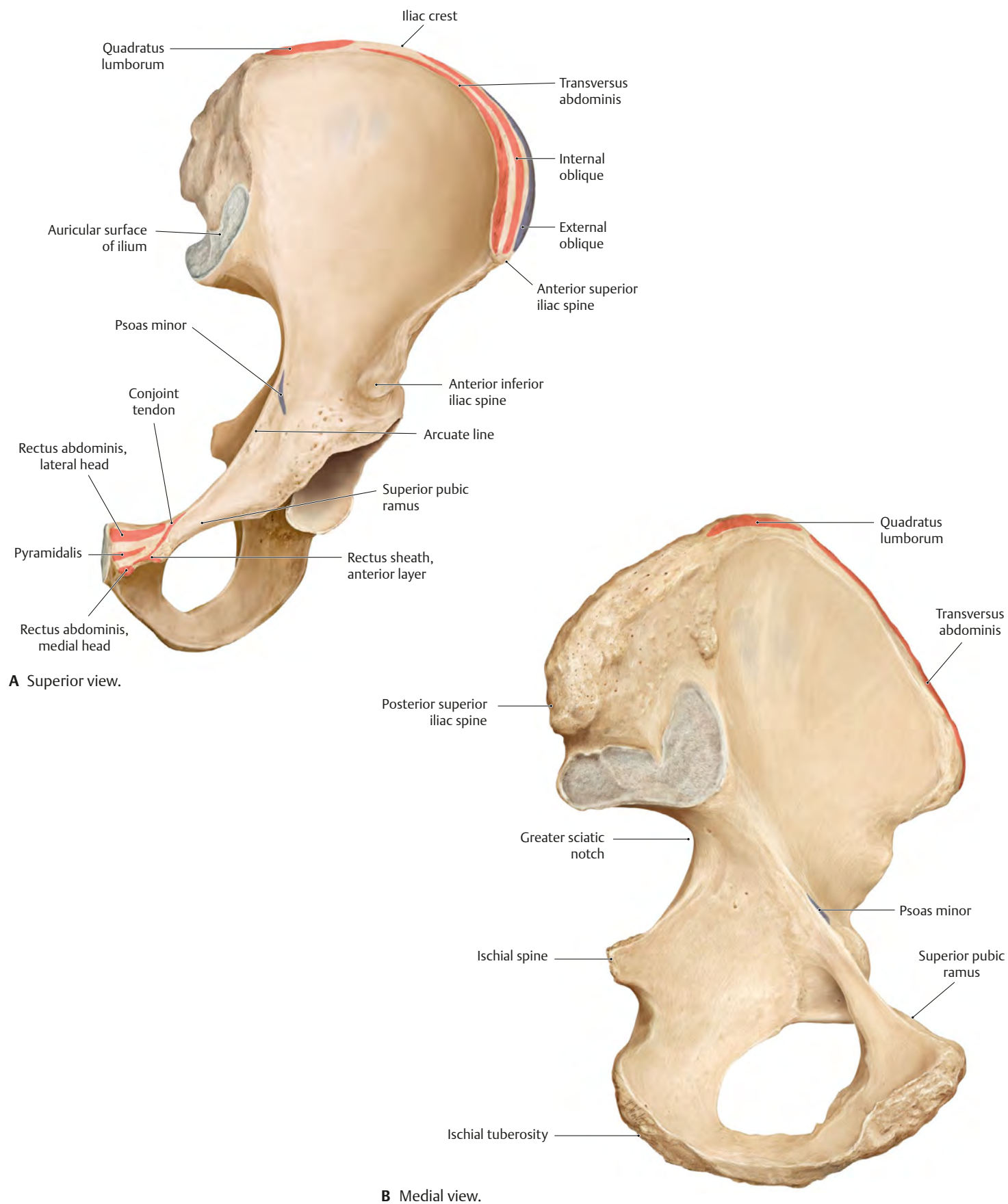


Fig 13.2 The inguinal ligament
Male pelvis, anterosuperior view.
The inguinal ligament is a palpable landmark that forms the demarcation between the abdominal wall and thigh. It is formed by the inferior edge of the external oblique aponeurosis, the most superficial of the anterior abdominal wall muscles. The inguinal ligament attaches laterally to the anterior superior iliac spine and medially to the pubic tubercle. It is important clinically as it forms the floor of the inguinal canal (see **Table 13.2**) and the roof of the retro-inguinal space (see **Fig. 34.31**).

Fig. 13.3 Abdominal wall muscle attachment sites

Left hip bone. Muscle origins are in red, insertions in blue.

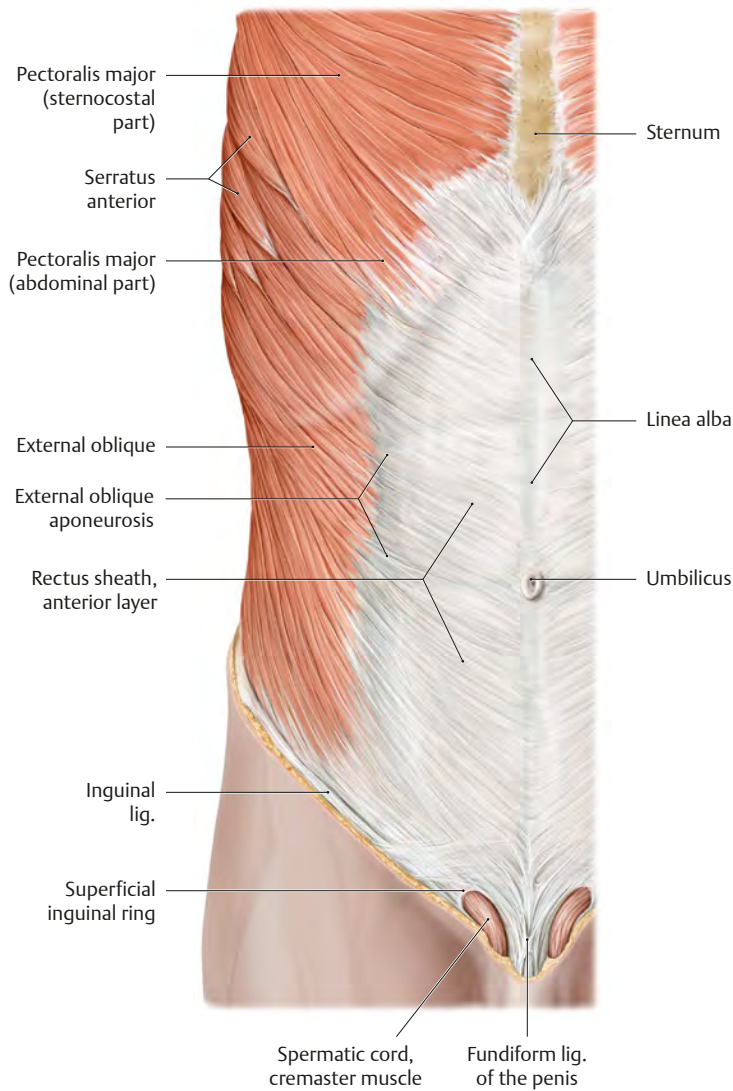


Muscles of the Anterolateral Abdominal Wall

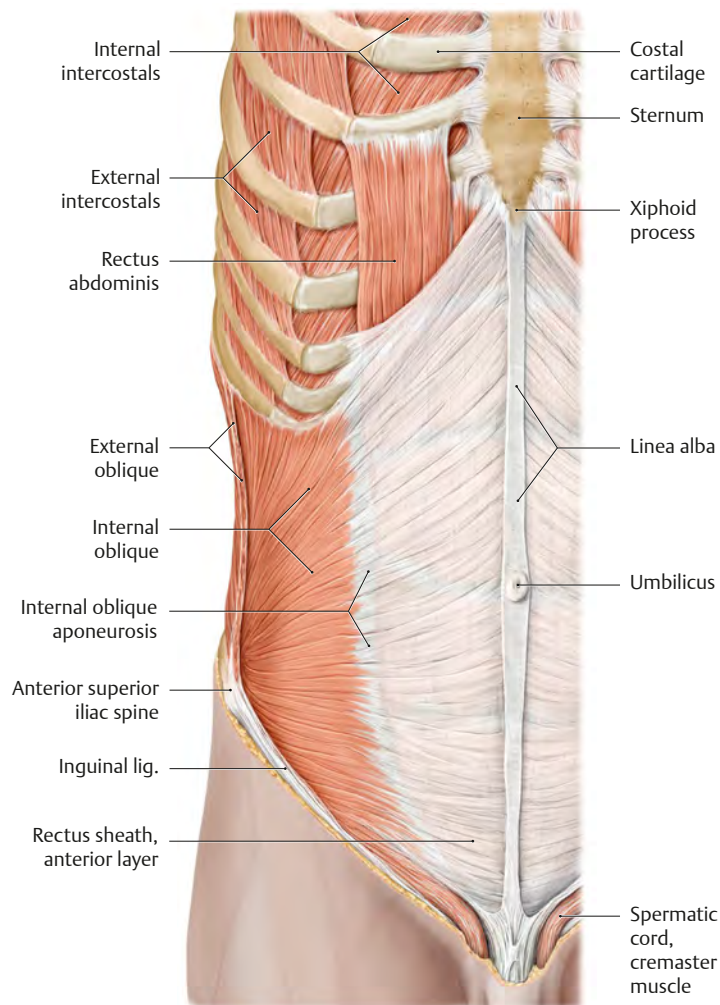
The muscles of the anterolateral abdominal wall consist of the external and internal obliques and the transversus abdominis. The posterior or

deep abdominal wall muscles (notably the psoas major) are functionally hip muscles (see p. 148).

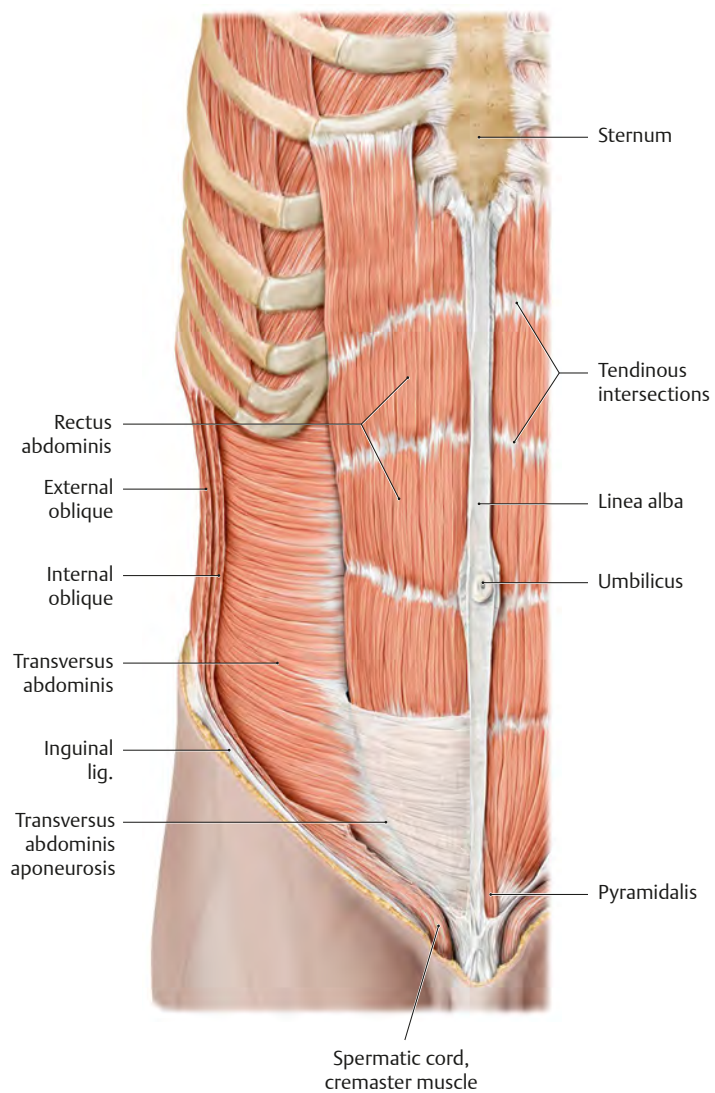
Fig. 13.4 Muscles of the abdominal wall
Right side, anterior view.



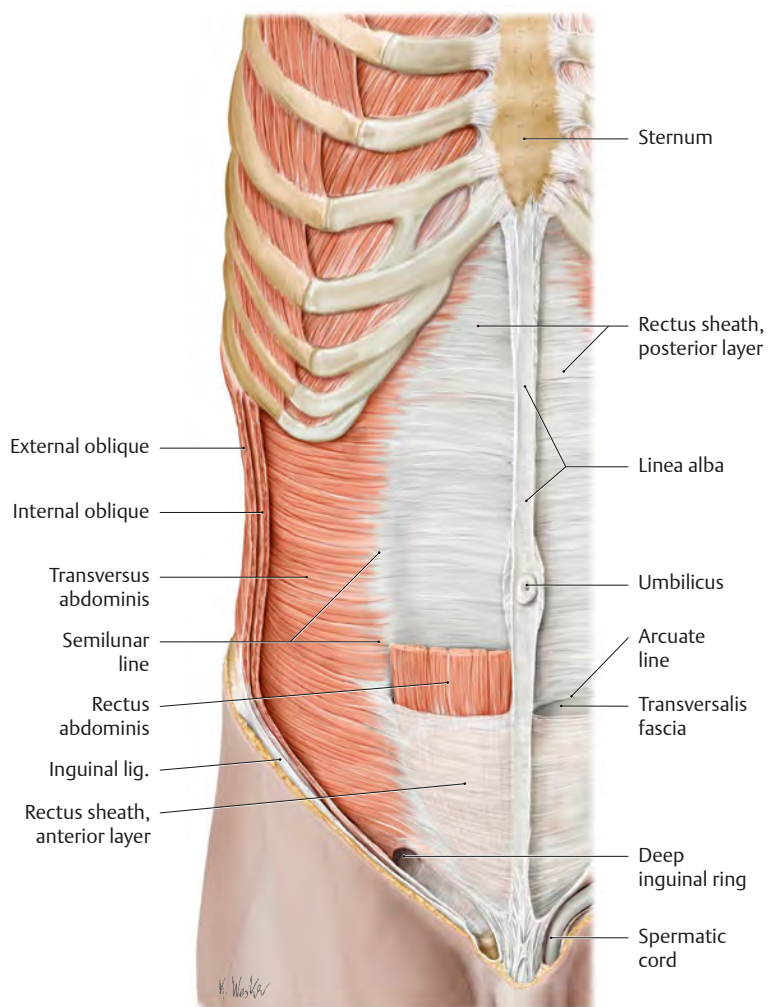
A Superficial abdominal wall muscles.



B Removed: External oblique, pectoralis major, and serratus anterior.



C Removed: External and internal obliques.



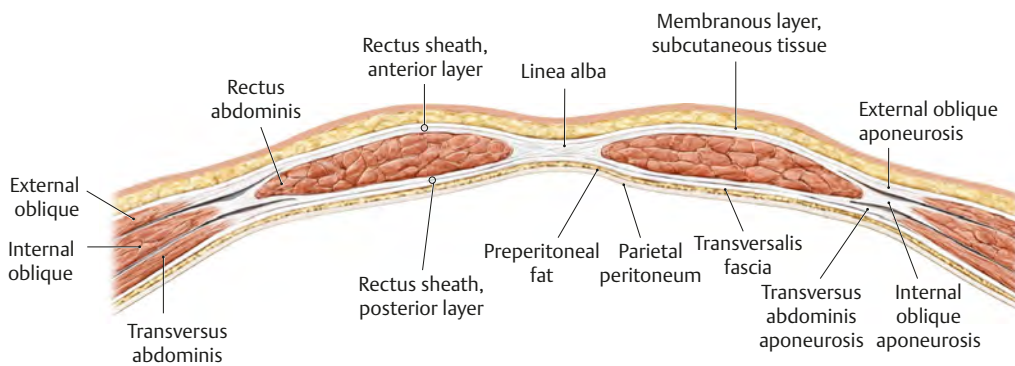
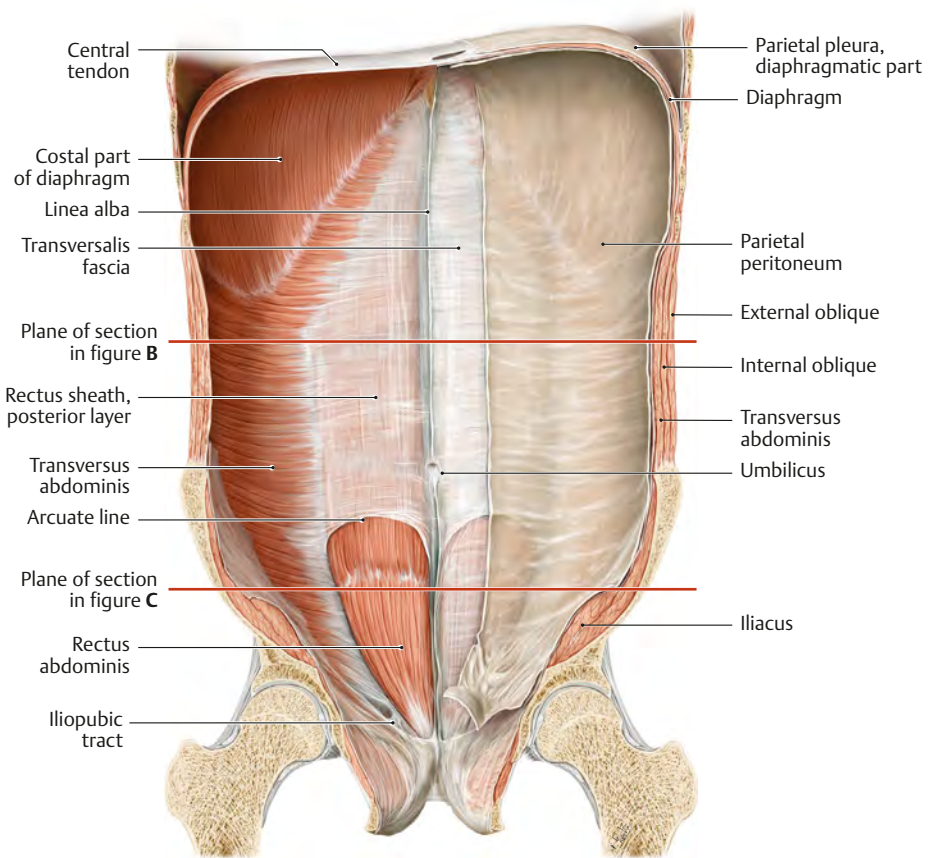
D Removed: Rectus abdominis.

Rectus Sheath & Posterior Abdominal Wall

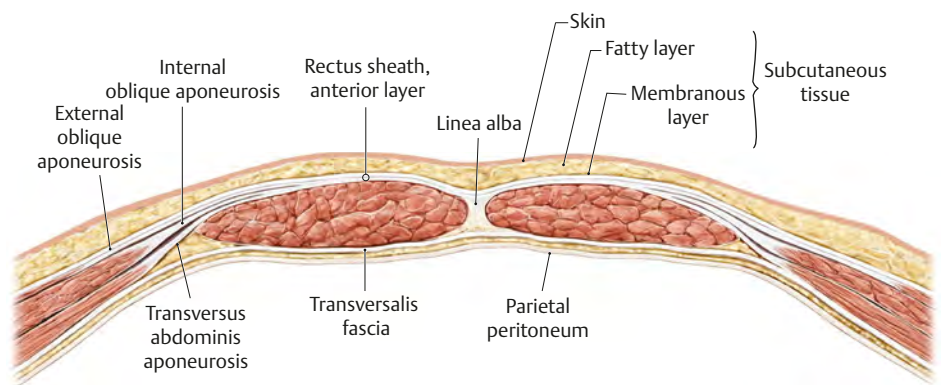
Fig. 13.5 The rectus sheath

The rectus sheath encloses the rectus abdominis and pyramidalis muscles on either side of the midline. Its anterior and posterior layers are formed by the aponeuroses of the anterolateral muscles as they split to pass around the rectus muscles. An arcuate line marks the inferior extent of the posterior layer, the point at which all of the aponeuroses pass anterior to the rectus muscles.

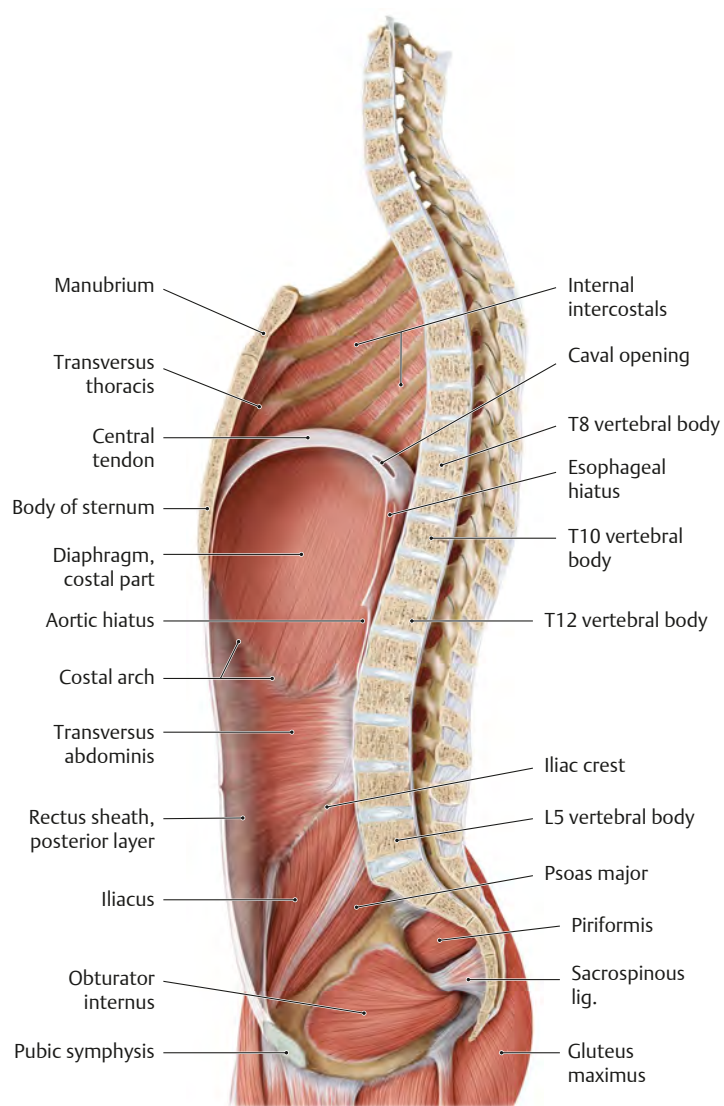
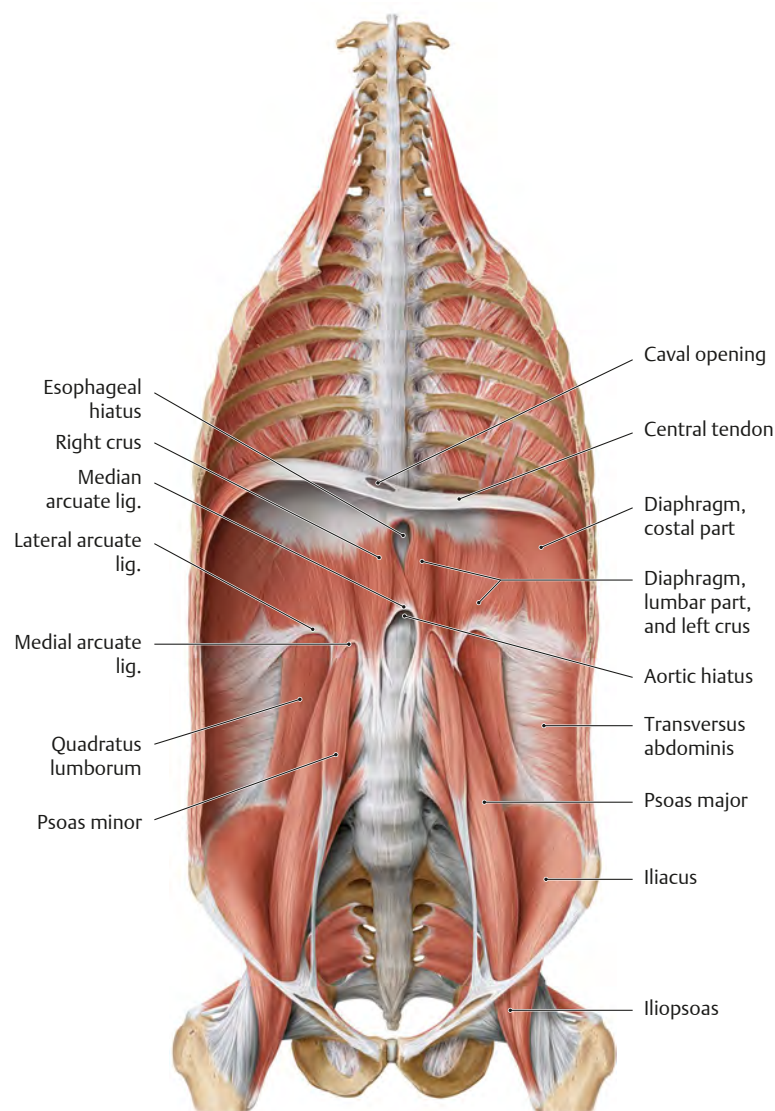
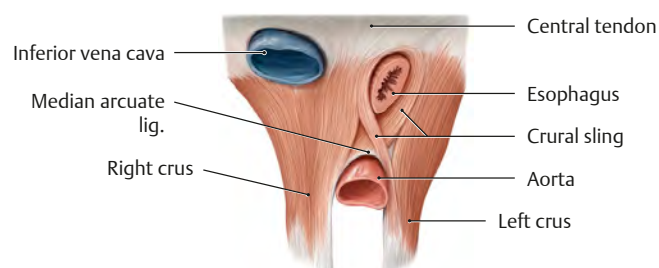
A Posterior (interior) view of the anterior abdominal wall. Peritoneum and transversalis fascia have been removed on the left side to reveal the rectus sheath.



B Section through the abdominal wall superior to the arcuate line.



C Section through the abdominal wall inferior to the arcuate line.

Fig. 13.6 Muscles of the posterior abdominal wall**A** Midsagittal section with diaphragm in intermediate position.**B** Coronal section with diaphragm in intermediate position.**C** Apertures of the diaphragm with vessels transected. Anterior view.

The caval opening is located to the right of the midline, those for the esophagus and aorta are to the left. Note that the crura of the diaphragm typically extend inferiorly as far as the L3 vertebra on the right and L2 vertebra on the left.

**Clinical box 13.1****Diaphragmatic hernias**

In diaphragmatic hernias, abdominal viscera prolapse into the thorax through a congenital or acquired opening in the diaphragm. By far the most common herniation site is the esophageal hiatus, accounting for 90% of cases. "Sliding" hernias, which account for 85% of these hiatal hernias, occur when the distal end of the esophagus and the cardia of the stomach slide upward into the thorax through the esophageal hiatus.

Abdominal Wall Muscle Facts

Fig. 13.7 Anterior abdominal wall muscles

Anterior view.

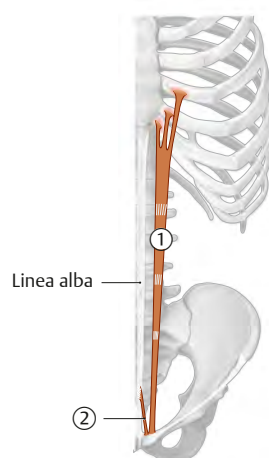


Fig. 13.8 Anterolateral abdominal wall muscles

Anterior view.

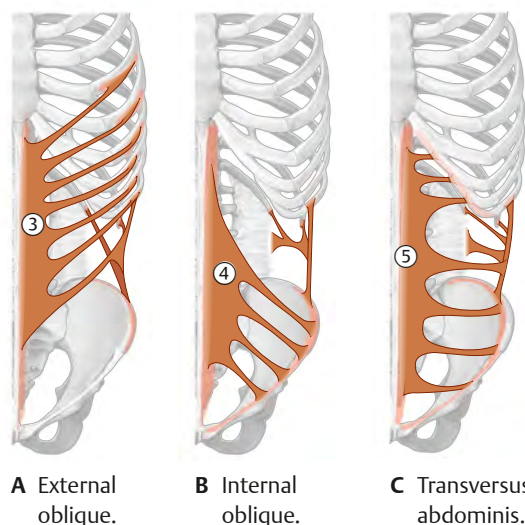


Fig. 13.9 Posterior abdominal wall muscles

Anterior view. The psoas major and iliacus are together known as the iliopsoas inferiorly.

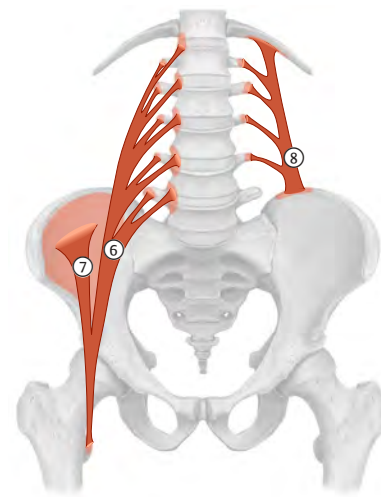


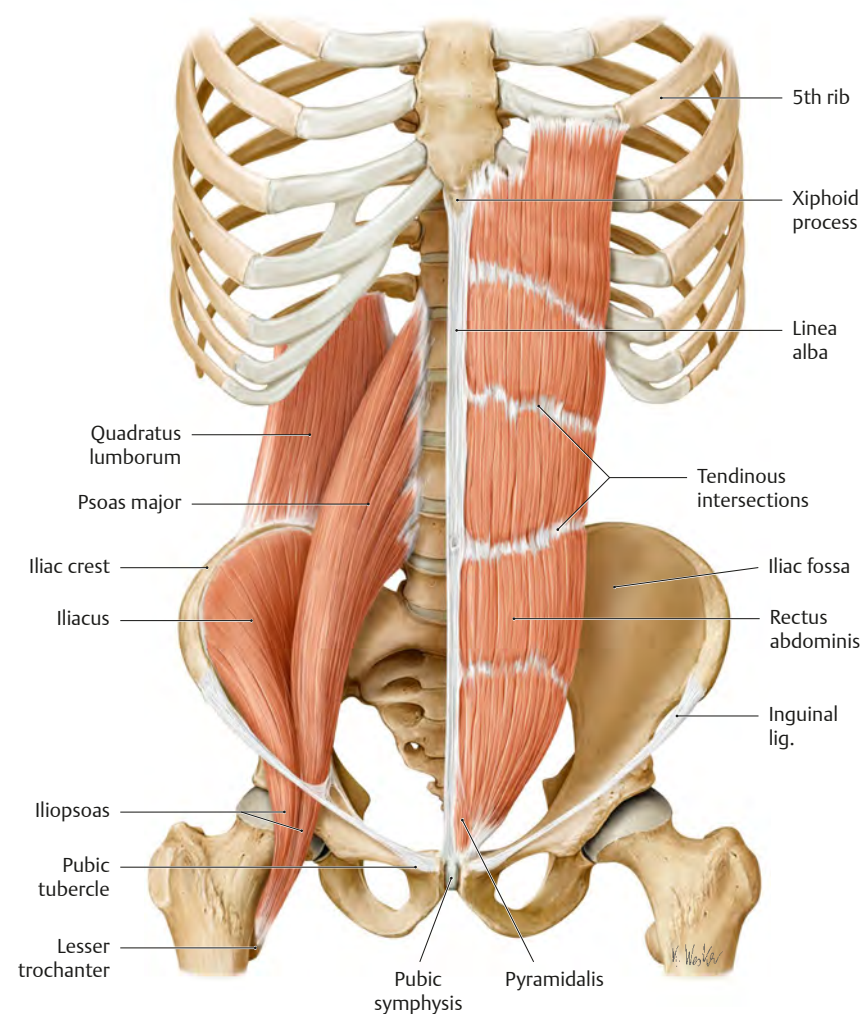
Table 13.1 Abdominal wall muscles

Muscle	Origin	Insertion	Innervation	Action
Anterior abdominal wall muscles				
① Rectus abdominis	<i>Lateral head:</i> Crest of pubis to pubic tubercle <i>Medial head:</i> Anterior region of pubic symphysis	Cartilages of 5th to 7th ribs, xiphoid process of sternum	Intercostal nn. (T5–T11), subcostal n. (T12)	Flexes trunk, compresses abdomen, stabilizes pelvis
② Pyramidalis	Pubis (anterior to rectus abdominis)	Linea alba (runs within the rectus sheath)	Subcostal n. (T12)	Tenses linea alba
Anterolateral abdominal wall muscles				
③ External oblique	5th to 12th ribs (outer surface)	Linea alba, pubic tubercle, anterior iliac crest	Intercostal nn. (T7–T11), subcostal n. (T12)	<i>Unilateral:</i> Flexes trunk to same side, rotates trunk to opposite side (external oblique) or same side (internal oblique)
④ Internal oblique	Thoracolumbar fascia (deep layer), iliac crest (intermediate line), anterior superior iliac spine, iliopsoas fascia	10th to 12th ribs (lower borders), linea alba (anterior and posterior layers)	Intercostal nn. (T7–T11), subcostal n. (T12)	<i>Bilateral:</i> Flexes trunk, compresses abdomen, stabilizes pelvis
⑤ Transversus abdominis	7th to 12th costal cartilages (inner surfaces), thoracolumbar fascia (deep layer), iliac crest, anterior superior iliac spine (inner lip), iliopsoas fascia	Linea alba, pubic crest	iliohypogastric n., ilioinguinal n.	<i>Unilateral:</i> Rotates trunk to same side <i>Bilateral:</i> Compresses abdomen
Posterior abdominal wall muscles				
Psoas minor* (see Fig. 31.19)	T12, L1 vertebrae and intervertebral disk (lateral surfaces)	Pectineal line, iliopubic ramus, iliac fascia; lowermost fibers may reach inguinal lig.		Weak flexor of the trunk
⑥ Psoas major	Superficial layer	T12–L4 vertebral bodies and associated intervertebral disks (lateral surfaces)	L1–L2 (L3) spinal nn.	Hip joint: Flexion and external rotation Lumbar spine (with femur fixed): <i>Unilateral:</i> Contraction flexes trunk laterally
	Deep layer	L1–L5 (costal processes)		
⑦ Iliacus	Iliac fossa	Femur (lesser trochanter), joint insertion as iliopsoas muscle	Femoral n. (L2–L4)	<i>Bilateral:</i> Contraction raises trunk from supine position
⑧ Quadratus lumborum	Iliac crest and iliolumbar lig. (not shown)	12th rib, L1–L4 vertebrae (costal processes)	Subcostal n. (T12), L1–L4 spinal nn.	<i>Unilateral:</i> Flexes trunk to same side <i>Bilateral:</i> Bearing down and expiration, stabilizes 12th rib

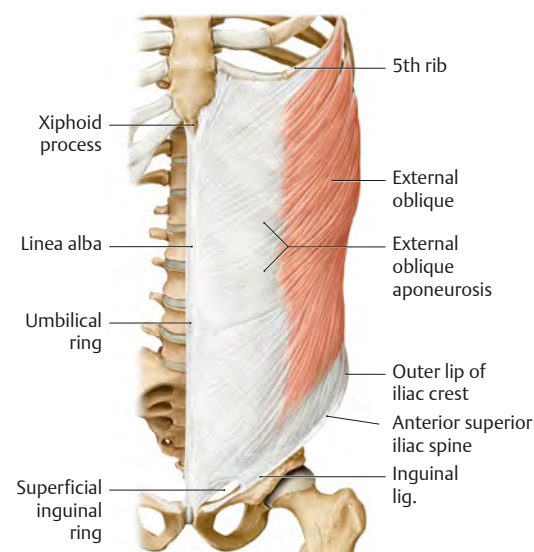
* Approximately 50% of the population has this muscle. For the diaphragm see pp. 64–65.

Fig. 13.10 Anterior, anterolateral, and posterior abdominal wall muscles

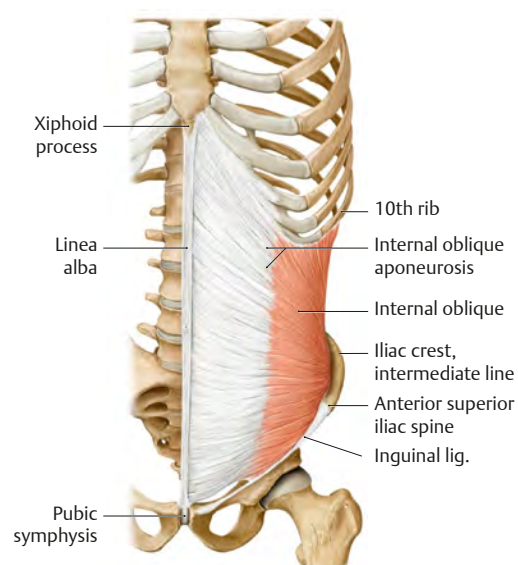
Anterior view.



A Anterior and posterior muscles.

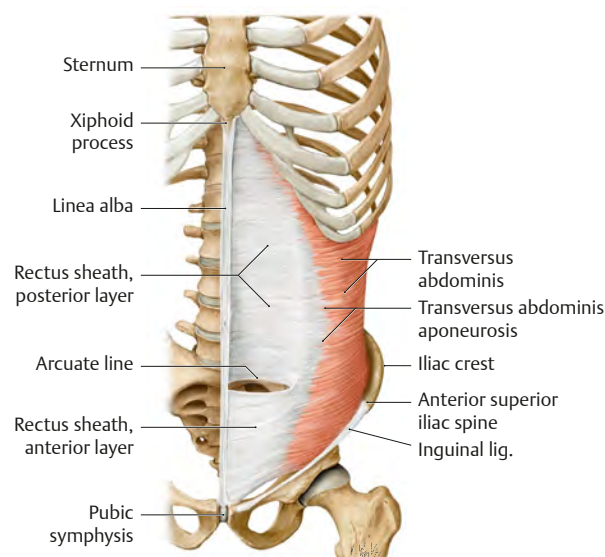
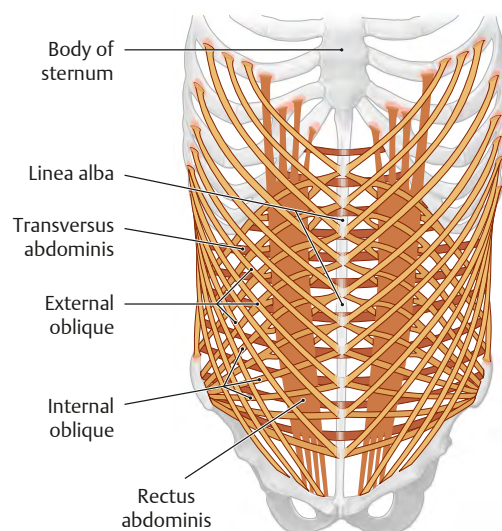


B External oblique.



C Internal oblique.

Fig. 13.11 Anterior and lateral abdominal wall muscles as a functional unit



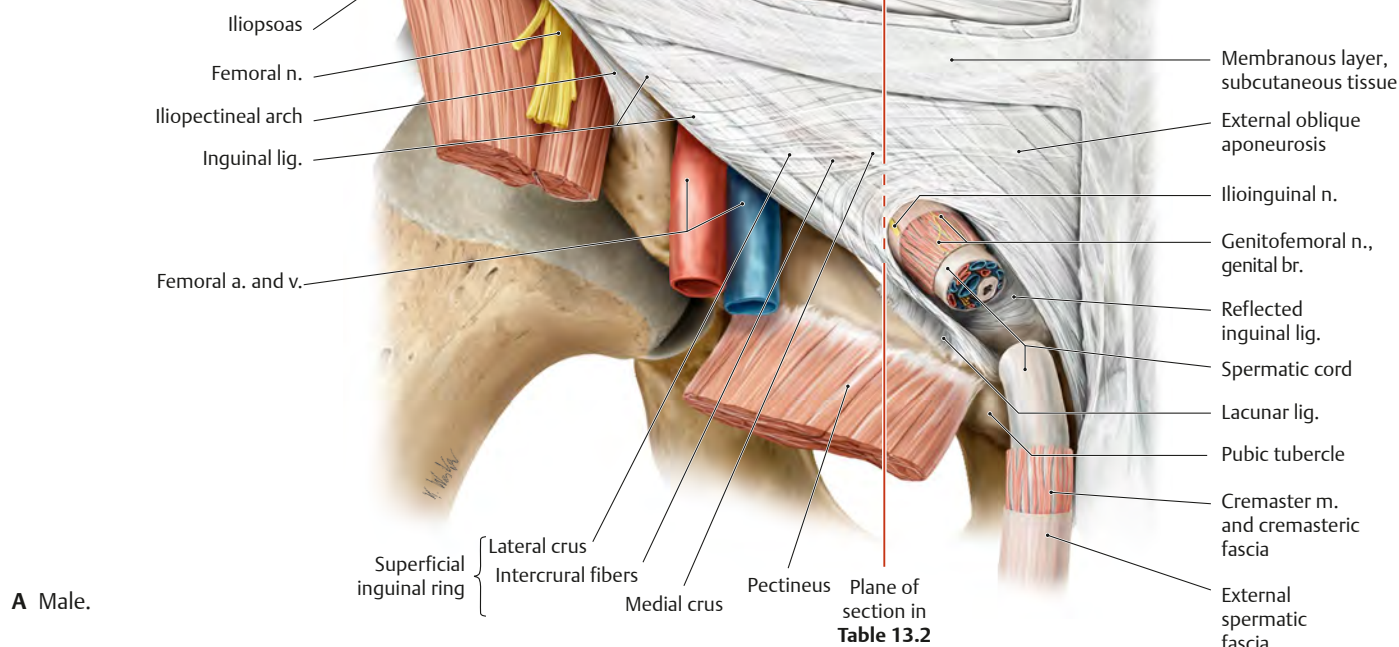
D Transversus abdominis.

Inguinal Region & Canal

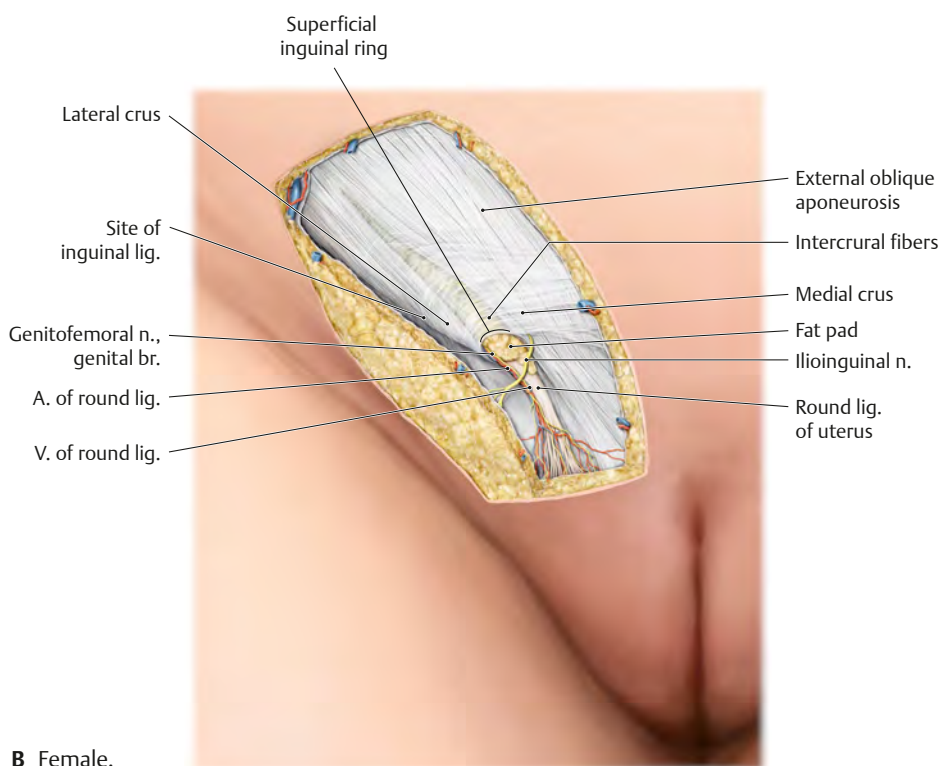
The inguinal region is the junction of the anterior abdominal wall and the anterior thigh. The inguinal canal in the male is an important site for the passage of structures into and out of the abdominal cavity (e.g., components of the spermatic cord).

Fig. 13.12 Inguinal region

Right side, anterior view.



A Male.



B Female.

Clinical box 13.2

Gender differences of the inguinal canal

The inguinal canal is an oblique pathway through the inferior part of the anterior abdominal wall. In the male, it represents the path through which the testis migrated from the posterior abdominal wall into the scrotum during the perinatal period. It's traversed by the spermatic cord (see Table 13.4), which connects the testis to the rest of the genitourinary system. The female inguinal canal is smaller and contains only the round ligament with its neurovasculature. This ligament is a remnant of the distal portion of the embryonic gubernaculum, a structure originally present in both males and females but which regresses in the male with descent of the testes.

Table 13.2 Structures of the inguinal canal

Structures		Formed by	
Wall	Anterior wall	①	External oblique aponeurosis
	Roof	②	Internal oblique m.
		③	Transversus abdominis m.
	Posterior wall	④	Transversalis fascia
		⑤	Parietal peritoneum
Openings	Floor	⑥	Inguinal lig. (densely interwoven fibers of the lower external oblique aponeurosis and adjacent fascia lata of the thigh)
	Superficial inguinal ring		Opening in external oblique aponeurosis; bounded by medial and lateral crus, intercrural fibers, and reflected inguinal lig.
	Deep inguinal ring		Outpouching of the transversalis fascia lateral to the lateral umbilical fold (inferior epigastric vessels)

Sagittal section through plane in Fig. 13.12A.

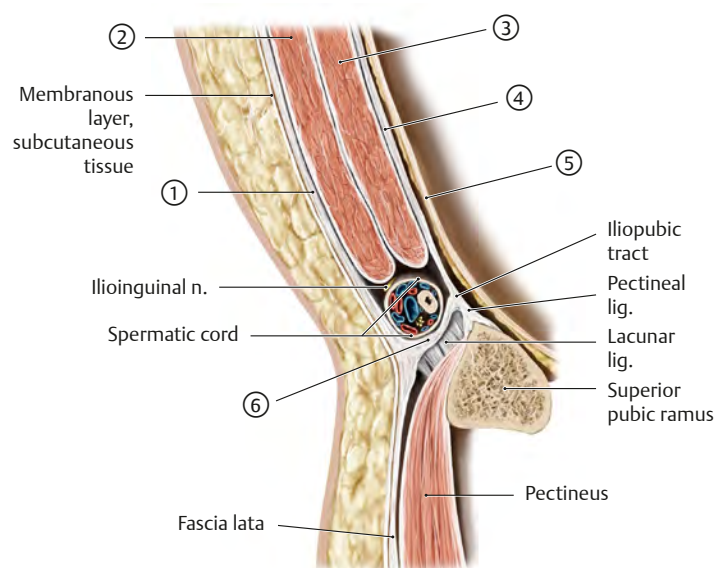
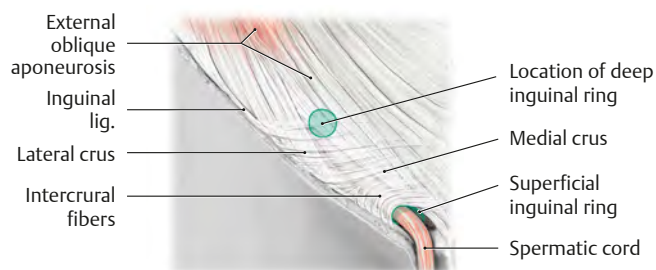
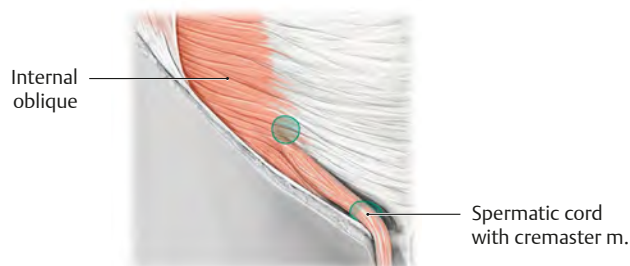


Fig. 13.13 Dissection of the male inguinal region

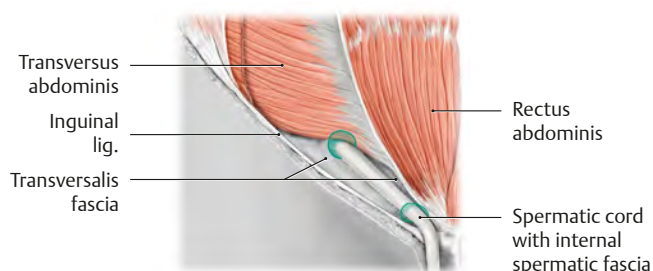
Right side, anterior view.



A Superficial layer.



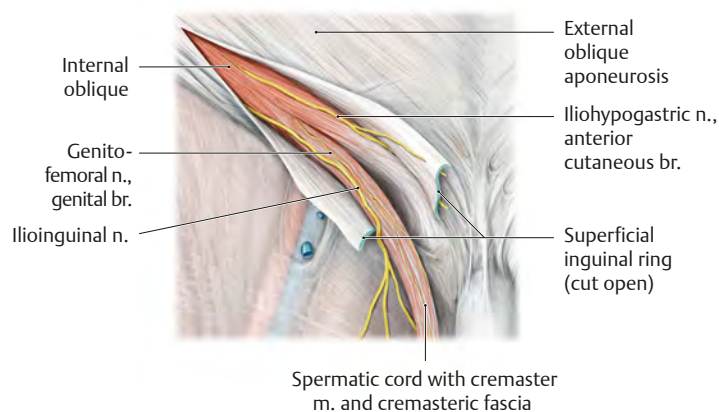
B Removed: External oblique aponeurosis.



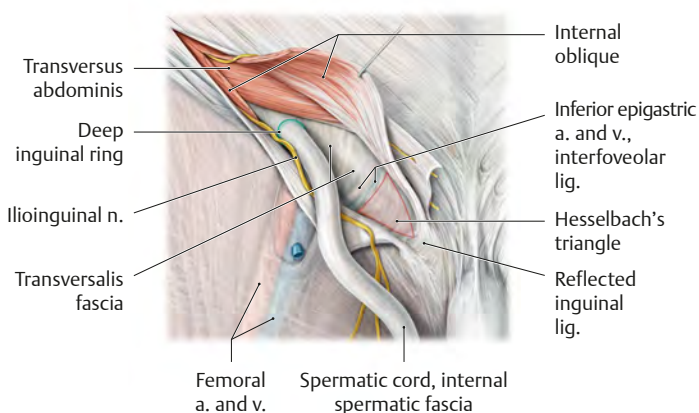
C Removed: Internal oblique m.

Fig. 13.14 Opening of the inguinal canal

Right side, anterior view.



A Divided: External oblique aponeurosis.



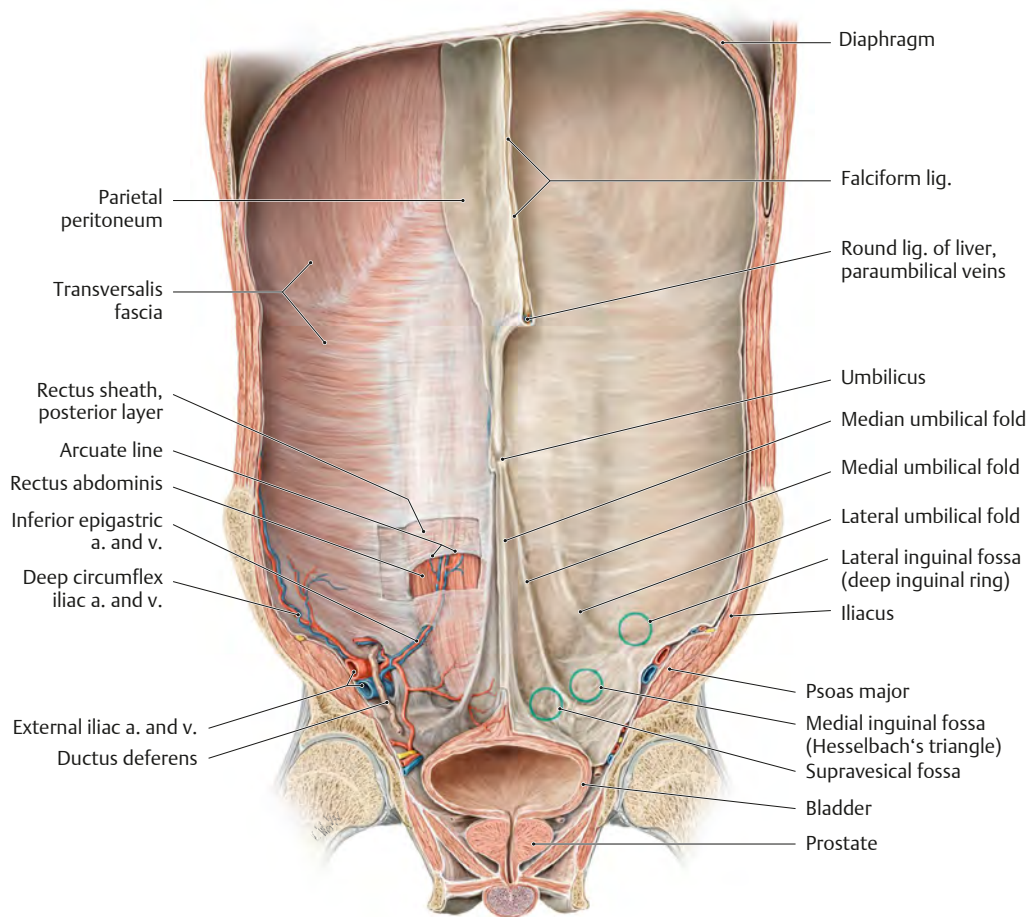
B Divided: Internal oblique and cremaster mm.

Inguinal Region & Inguinal Hernias

Fig. 13.15 Sites of herniation through the anterior abdominal wall

Coronal section, male, posterior (internal) view.

A The three fossae of the anterior abdominal wall (circled) are sites of potential herniation through the wall.



B Internal hernial openings in the male inguinal region. Detail from **A**. Peritoneum and transversalis fascia have been removed to reveal the hernia openings. Color shading indicates openings for supravascular (green), indirect (teal) and direct (purple) hernias (see **Table 13.3**).

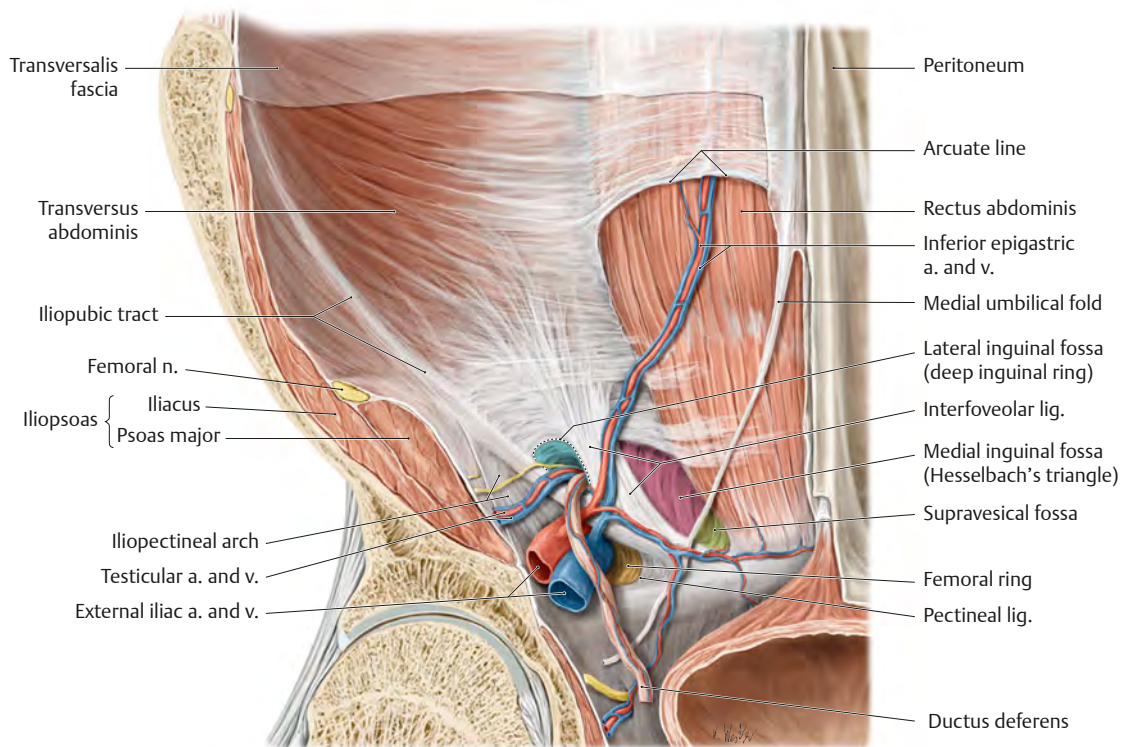


Fig. 13.16 Schematic of the male inguinal canal and its relation to structures of the abdominal wall

Right side, anterior view.

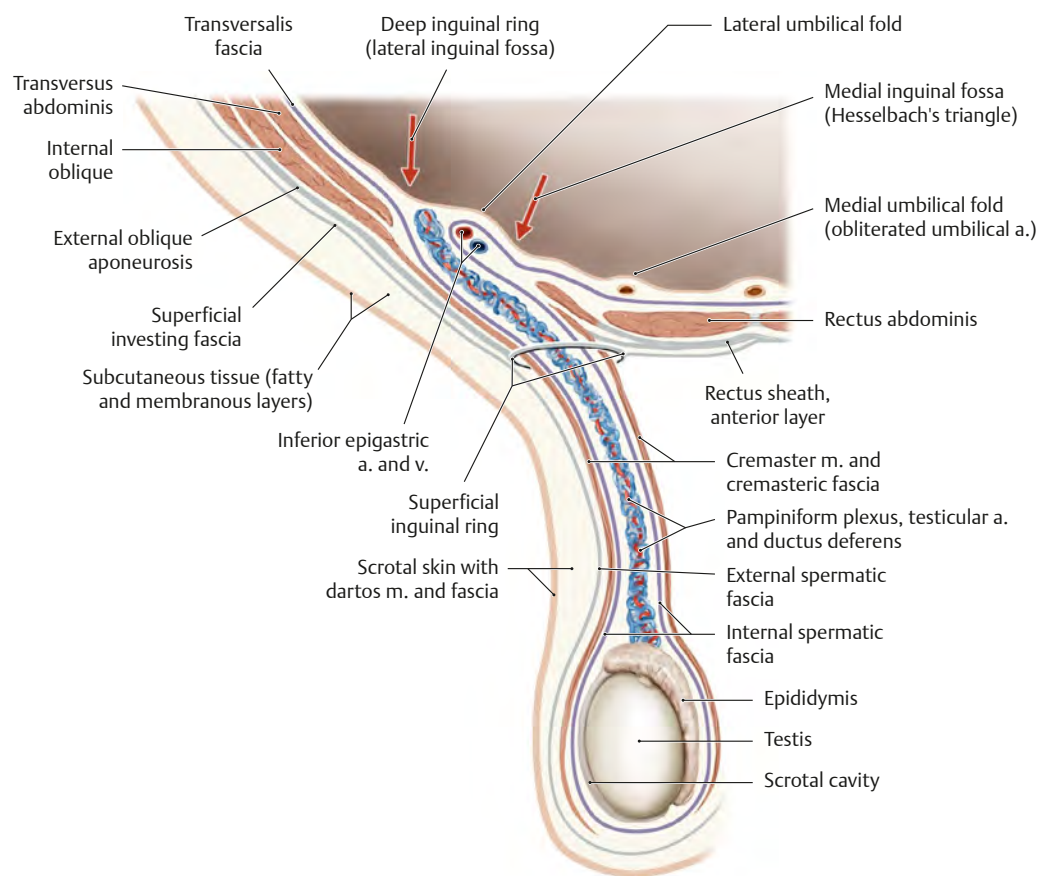
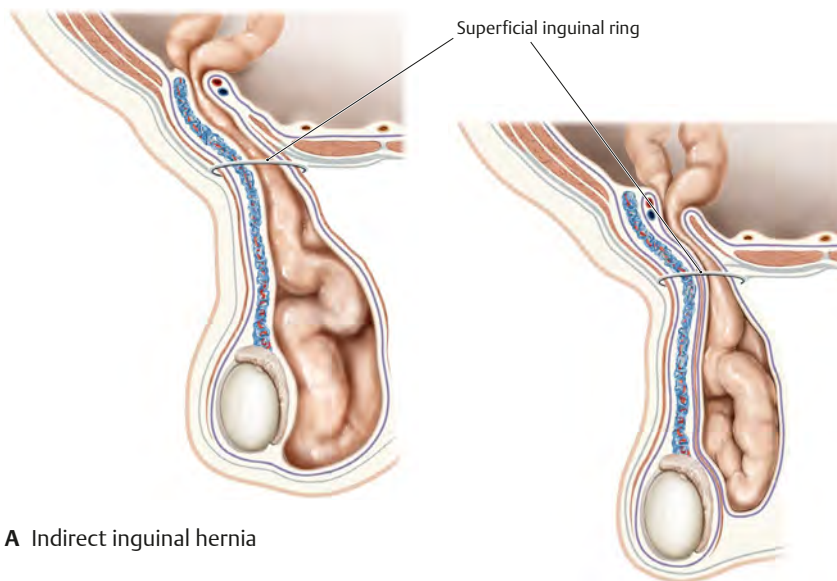


Table 13.3

Hernias of the inguinal region

Most inguinal hernias occur in males. All are located above the inguinal ligament and, if large enough, protrude externally through the superficial ring. However, the internal site of origin, and therefore structure of the hernia sac (covering), differ among types. Femoral hernias, more common in women, originate at the femoral ring below the inguinal ligament and emerge at the saphenous opening in the thigh.

Hernia type	Site of origin	Hernia sac
Indirect inguinal (congenital or acquired)	Lateral inguinal fossa (deep inguinal ring) lateral to inferior epigastric vessels	Peritoneum, transversalis fascia, cremaster m.
Direct inguinal (acquired)	Medial inguinal fossa (Hesselbach's triangle), medial to inferior epigastric vessels	Peritoneum, transversalis fascia
Femoral	Femoral ring, inferior to inguinal lig.	Cribiform fascia of saphenous opening



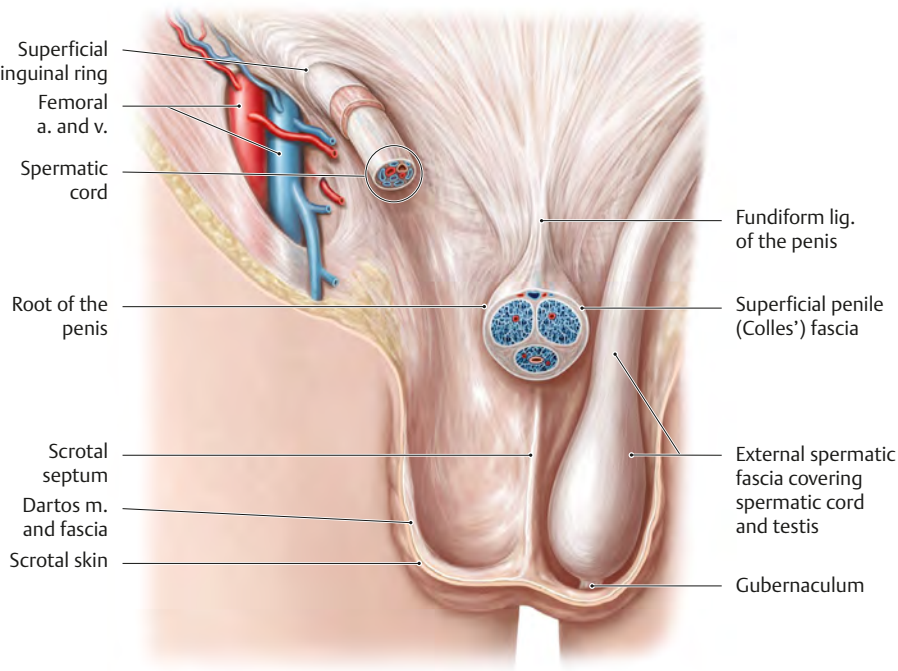
A Indirect inguinal hernia

B Direct inguinal hernia

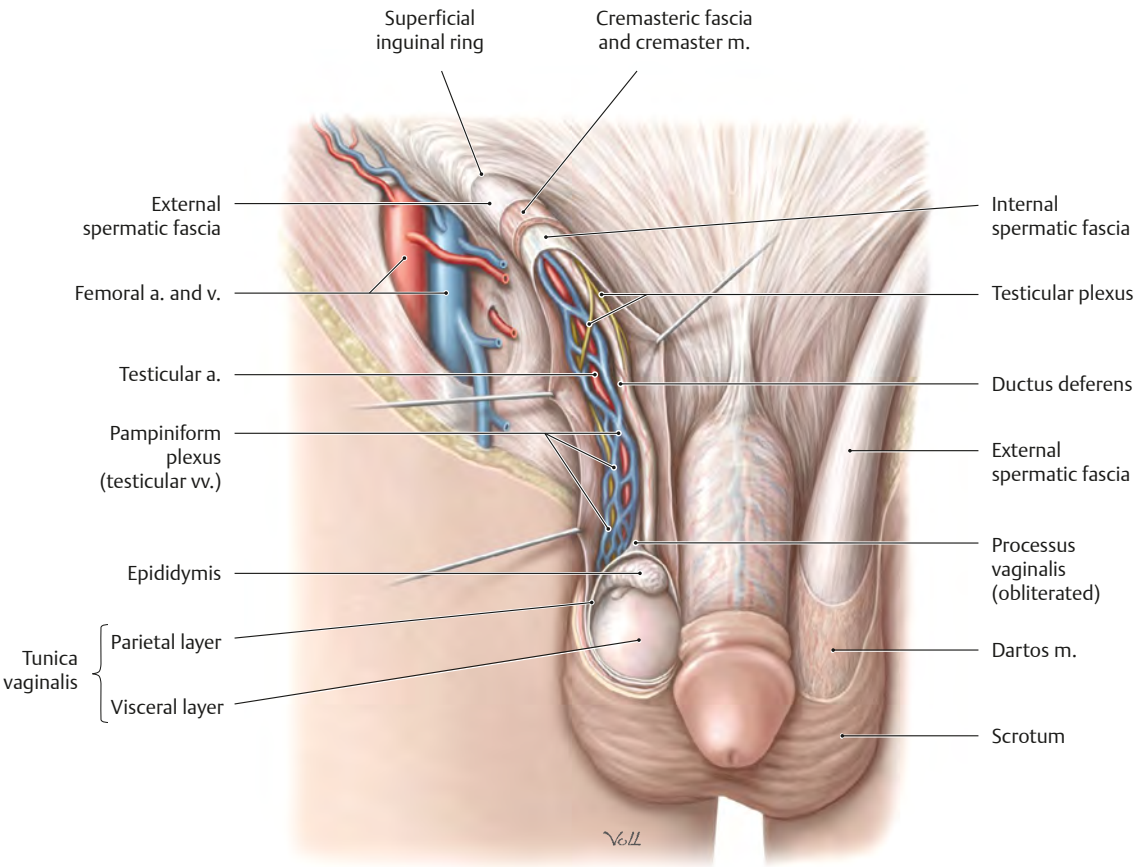
Scrotum & Spermatic Cord

The coverings of the scrotum, testis, and spermatic cord are continuations of muscular and fascial layers of the anterior abdominal wall, as are those of the inguinal canal.

Fig. 13.17 Scrotum and spermatic cord
Anterior view.



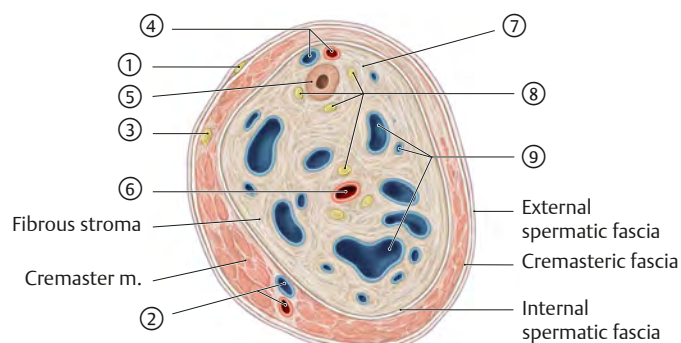
A Structure and contents of the scrotum.



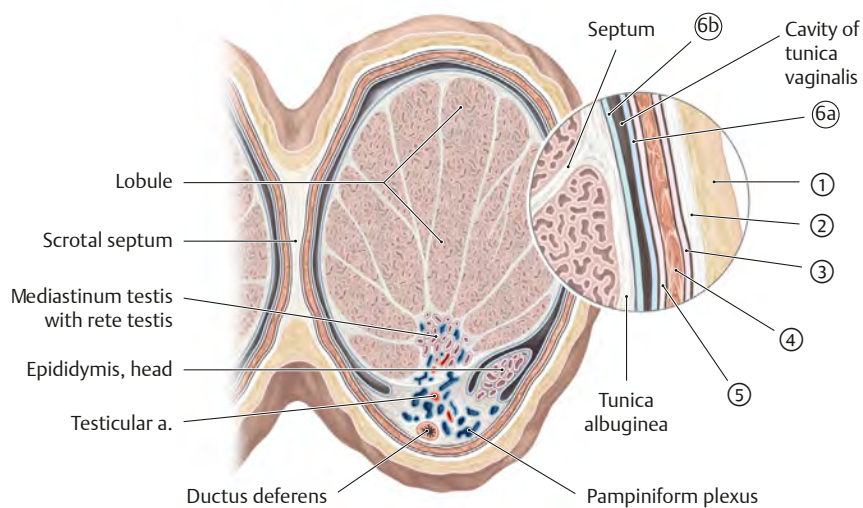
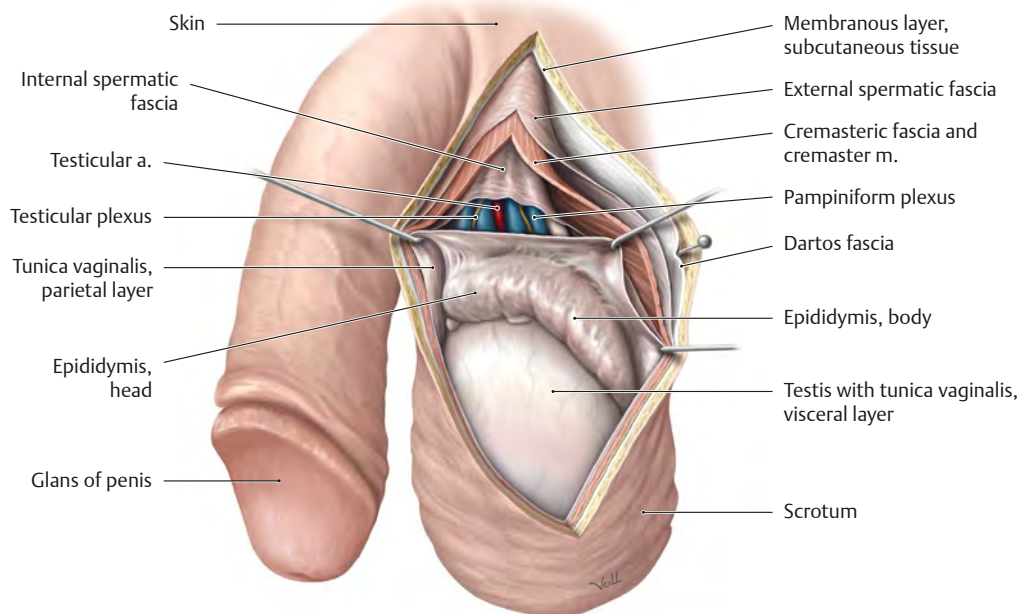
B Fascial and muscular layers of the spermatic cord have been opened to reveal its contents.

Table 13.4 Contents of the spermatic cord

Surrounding layer	Contents
External spermatic fascia	① Ilioinguinal n.
Cremasteric muscle	② Cremasteric a. and v. ③ Genitofemoral n., genital br.
Internal spermatic fascia	④ A. and v. of ductus deferens ⑤ Ductus deferens ⑥ Testicular a. ⑦ Processus vaginalis (obliterated) ⑧ Testicular (nerve) plexus ⑨ Pampiniform (venous) plexus

**Fig. 13.18** Testis and epididymis

Left lateral view.



Transverse section through right testis, superior view.

Table 13.5 Coverings of the testis

Covering layer	Derived from
① Scrotal skin	Abdominal skin
② Dartos m. and fascia	Membranous layer, subcutaneous tissue
③ External spermatic fascia	External oblique aponeurosis and superficial investing fascia
④ Cremaster m. and cremasteric fascia	Internal oblique m.
⑤ Internal spermatic fascia	Transversalis fascia
⑥a Tunica vaginalis, parietal layer	Peritoneum
⑥b Tunica vaginalis, visceral layer	

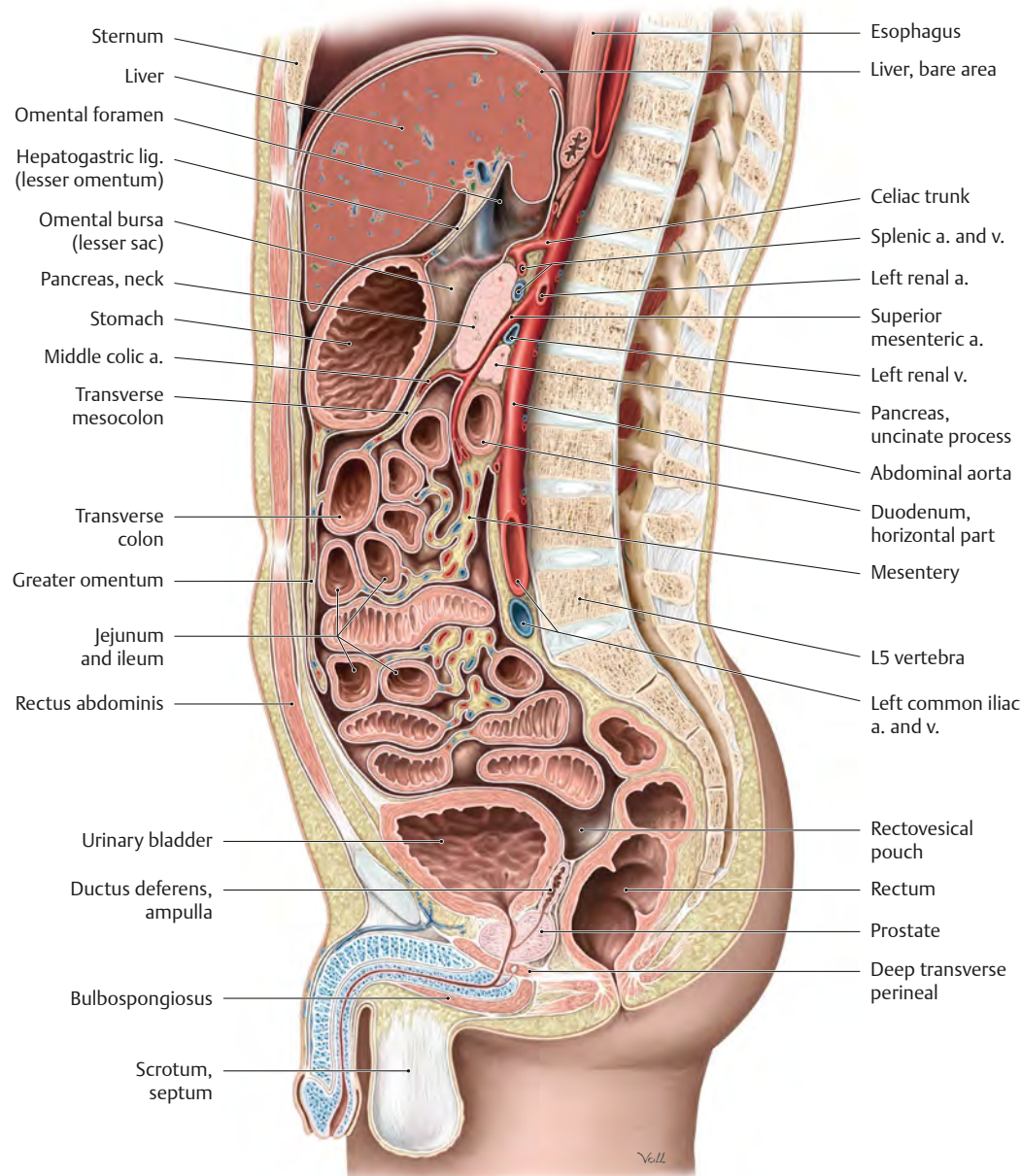
* The transversus abdominis has no contribution to the spermatic cord or covering of the testis.

14 Abdominal Cavity & Spaces

Divisions of the Abdominopelvic Cavity

Fig. 14.1 Organs of the abdominopelvic cavity

Midsagittal section, male, viewed from the left.



Clinical box 14.1

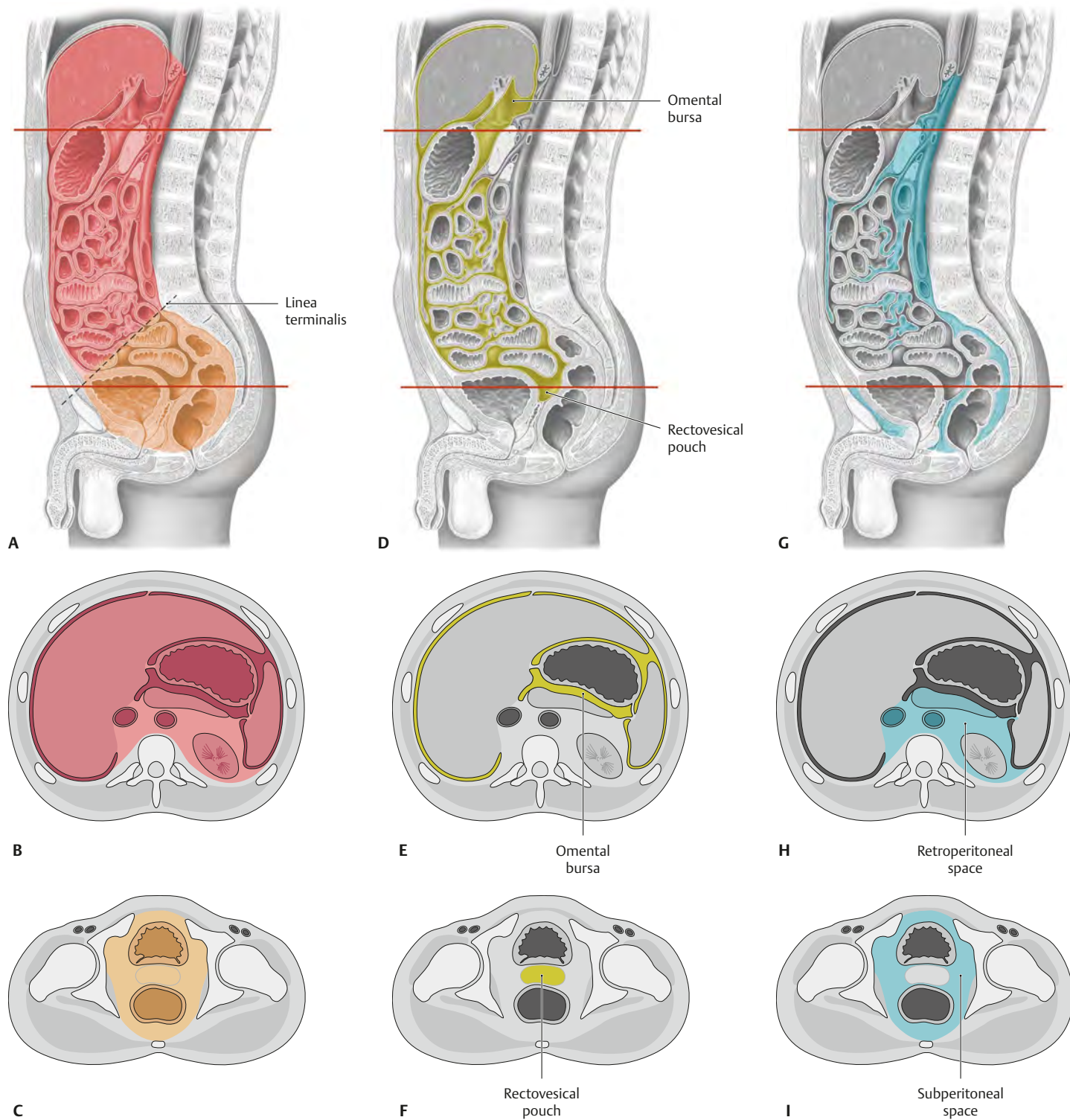
Acute abdominal pain

Acute abdominal pain ("acute abdomen") may be so severe that the abdominal wall becomes extremely sensitive to touch ("guarding") and the intestines stop functioning. Causes include organ inflammation such

as appendicitis, perforation due to a gastric ulcer (see **p. 167**), or organ blockage by a stone, tumor, etc. In women, gynecological processes or ectopic pregnancies may produce severe abdominal pain.

Fig. 14.2 Divisions of the pelvic and abdominal cavities

Each column of diagrams shows a midsagittal section viewed from the left side, as well as two axial sections, one at the L1 level and the other at the lower part of the sacrum, both viewed from below.



A–C Topography of body cavities: abdominal cavity and pelvic cavity (imaginary line separating the two cavities is the linea terminalis).

D–F Serous cavities (peritoneal spaces): abdominal peritoneal cavity and pelvic peritoneal cavity.

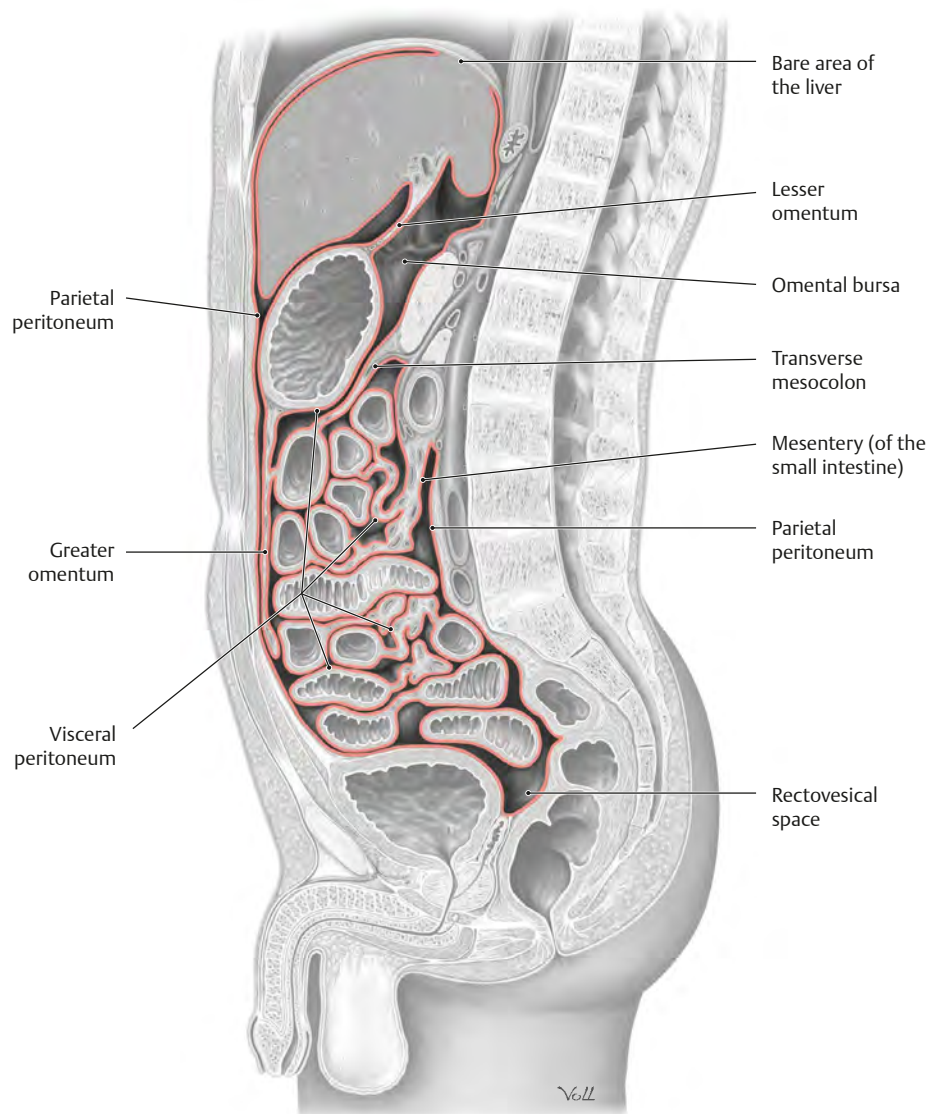
G–I Connective tissue spaces (extraperitoneal spaces): retroperitoneal space and subperitoneal space; serous cavities and extraperitoneal spaces are separated by peritoneum.

Peritoneum, Mesenteries & Omenta

Organs in the abdominopelvic cavity are classified by the presence of surrounding peritoneum (the serous membrane lining the cavity) and

a mesentery (a double layer of peritoneum that connects the organ to the abdominal wall) (see **Table 14.1**).

Fig. 14.3 Peritoneal cavity



A Midsagittal section through the male abdominopelvic cavity, viewed from the left. The peritoneum is shown in red.



Clinical box 14.2

Peritonitis and ascites

Bacterial contamination of the peritoneum following surgery or rupture of an inflamed organ (duodenum, gallbladder, appendix) results in peritonitis, inflammation of the peritoneum. It is accompanied by severe abdominal pain, tenderness, nausea, and fever and can be fatal when generalized throughout the peritoneal cavity. It often results in ascites, the accumulation of excess peritoneal fluid due to a change in concentration gradients that

results in loss of capillary fluid. Ascites can also accompany other pathologic conditions, such as metastatic liver cancer and portal hypertension. In these cases, many liters of ascitic fluid can accumulate in the peritoneal cavity. The fluid is aspirated by paracentesis. The needle is carefully inserted through the abdominal wall so as to avoid the urinary bladder and inferior epigastric vessels.

Fig. 14.4 Schematic showing peritoneal relations of intraperitoneal and extraperitoneal (primary and secondary retroperitoneal) organs of the abdomen

Transverse section, superior view (See Table 14.2).

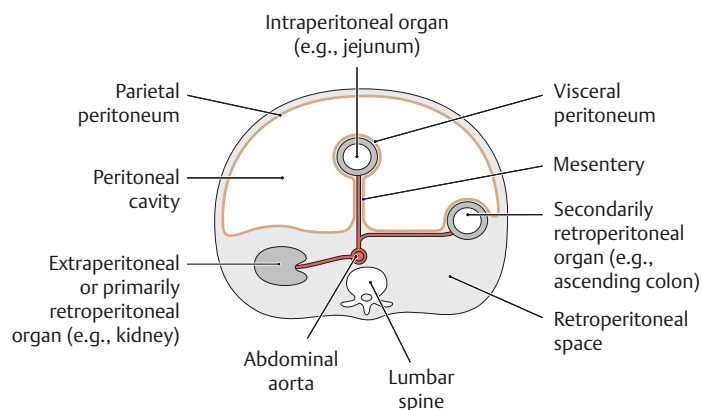


Fig. 14.5 Relationship of an intraperitoneal organ to the mesentery and peritoneum

Arrows indicate blood vessels in the mesentery.

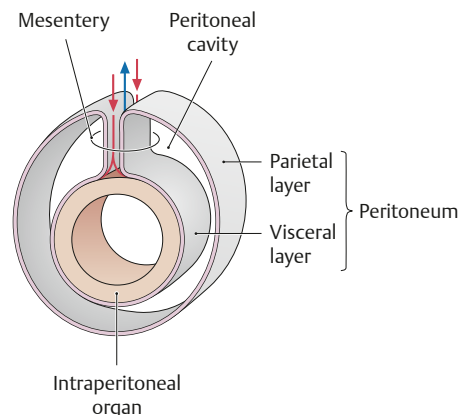


Fig. 14.6 Structure of the greater and lesser omenta and their relation to the omental bursa

Sagittal section, left lateral view.

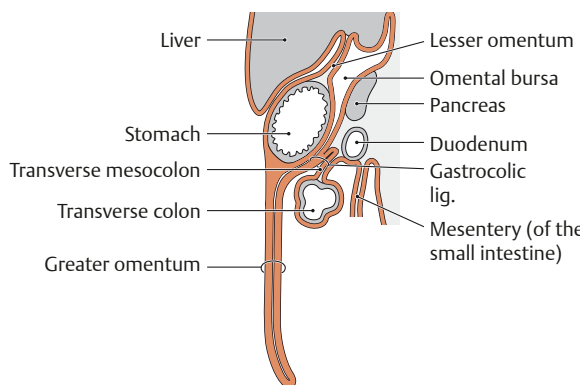


Table 14.1

Mesenteries and omenta

Mesenteries	Mesentery (of the small intestine)
	Transverse mesocolon
	Sigmoid mesocolon
	Mesoappendix
Omenta	Lesser omentum
	Greater omentum
Reflections of the peritoneum that connect organs to the body wall or to another organ allow normal mobility of the gastrointestinal tract while preventing excessive movement. A mesentery is a double layer of peritoneum that connects intraperitoneal organs to the posterior abdominal wall and transmits nerves and vessels. An omentum is a double layer of peritoneum that connects the stomach and duodenum to another organ or to the posterior abdominal wall.	

Table 14.2

Organs of the abdominopelvic cavity classified by their relationship to the peritoneum

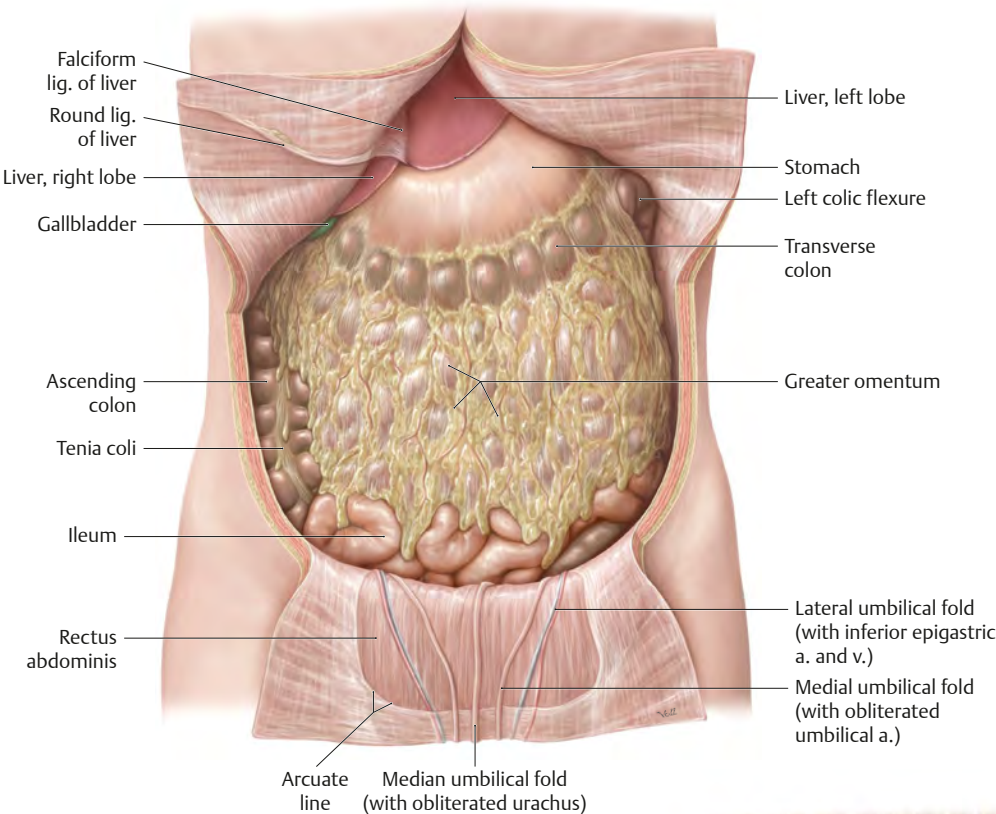
Location		Organs		
Intraperitoneal organs: These organs have a mesentery and are completely covered by the peritoneum.				
Abdominal peritoneal		• Stomach • Small intestine (jejunum, ileum, some of the superior part of the duodenum) • Spleen • Liver	• Gallbladder • Cecum with vermiform appendix (portions of variable size may be retroperitoneal) • Large intestine (transverse and sigmoid colons)	
Pelvic peritoneal		• Uterus (fundus and body)	• Ovaries	• Uterine tubes
Extraperitoneal organs: These organs either have no mesentery or lost it during development.				
Retroperitoneal	Primarily	• Kidneys and ureters	• Suprarenal glands	• Uterine cervix
	Secondarily	• Duodenum (descending, horizontal, and ascending) • Pancreas	• Ascending and descending colon and cecum • Rectum (upper 2/3)	
Infraperitoneal/subperitoneal		• Urinary bladder • Distal ureters • Prostate	• Seminal glands • Uterine cervix	• Vagina • Rectum (lower 1/3)

Mesenteries & Peritoneal Recesses

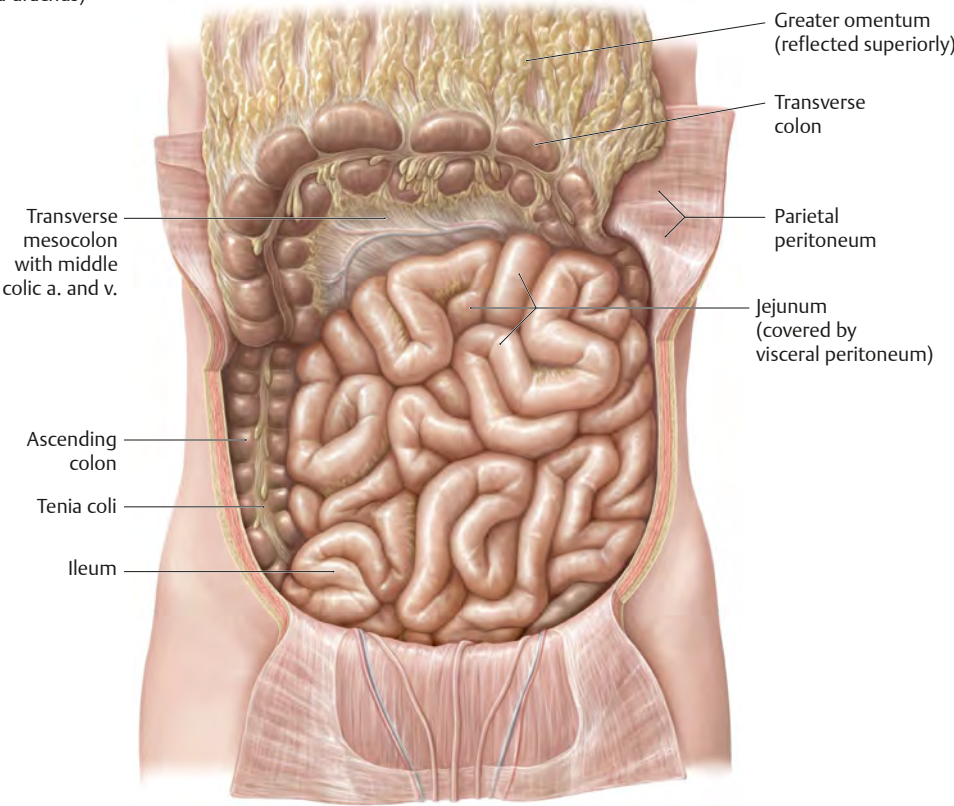
The peritoneal cavity is divided into the large greater sac and small omental bursa (lesser sac). The greater omentum is an apron-like fold of peritoneum suspended from the greater curvature of the stomach and covering the anterior surface of the transverse colon. The attach-

ment of the transverse mesocolon on the anterior surface of the descending part of the duodenum and the pancreas divides the peritoneal cavity into a supracolic compartment (liver, gallbladder, and stomach) and an infracolic compartment (intestines).

Fig. 14.7 Dissection of the peritoneal cavity
Anterior view.

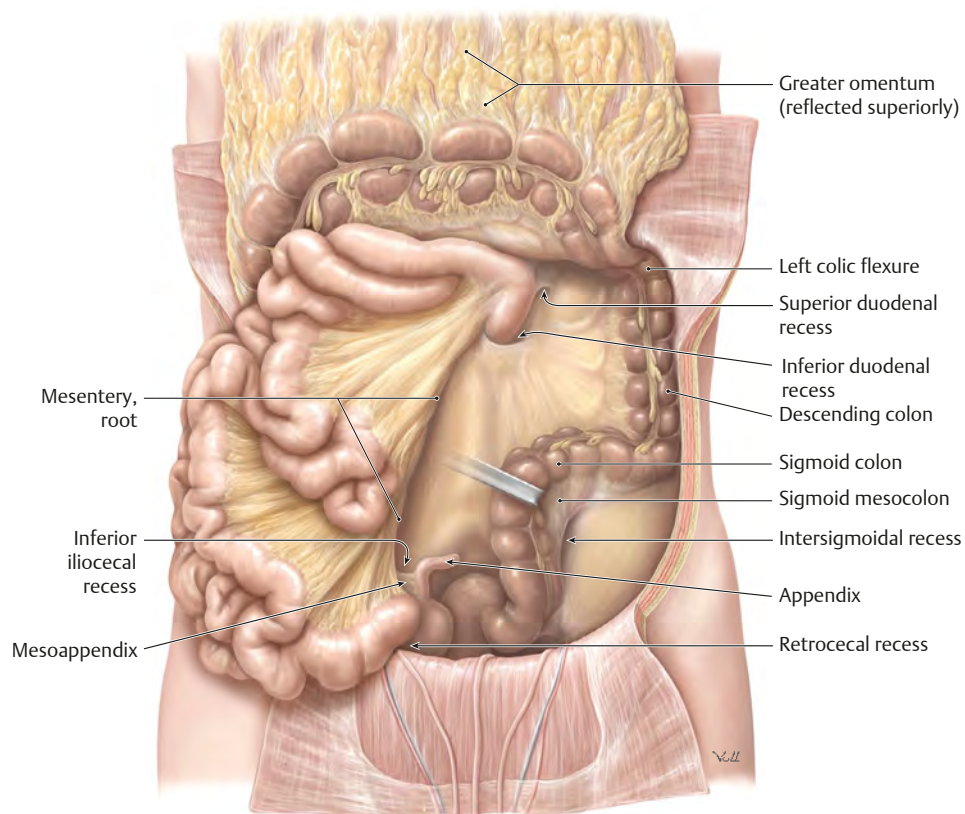
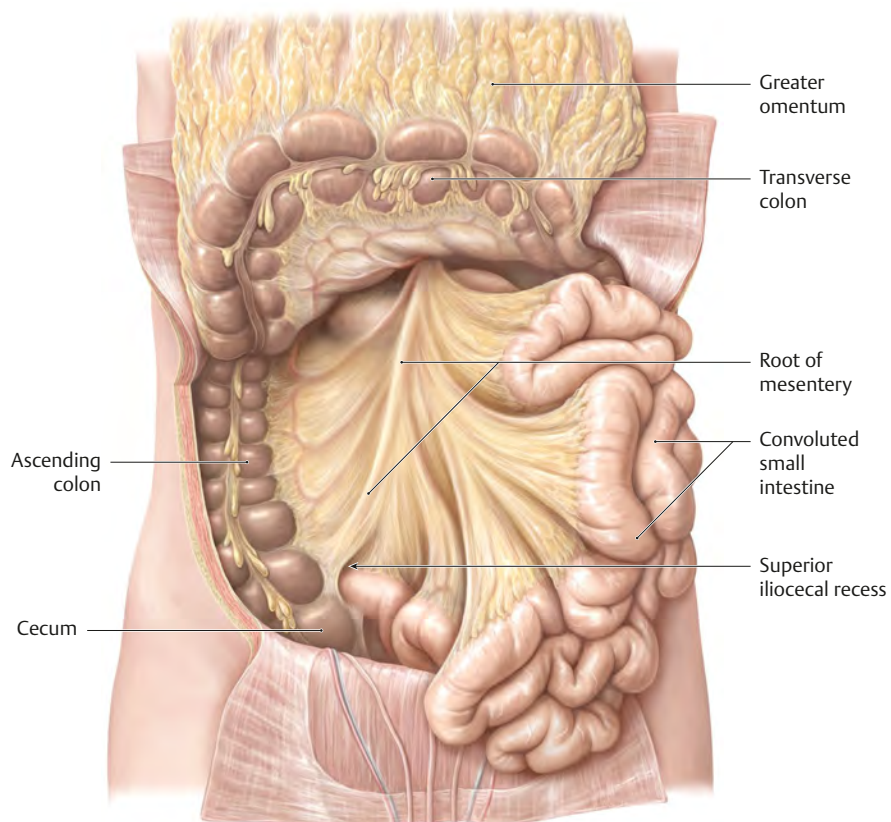


A Greater sac. *Retracted*: Abdominal wall.



B Infracolic compartment, the portion of the peritoneal cavity below the attachment of the transverse mesocolon. *Reflected*: Greater omentum and transverse colon.

C Mesentery (of the small intestine). *Reflected:* Greater omentum, transverse colon, small intestine.



D Mesenteries and mesenteric recesses in the infracolic compartment. *Reflected:* Greater omentum, transverse colon, small intestines, and sigmoid colon.

Lesser Omentum & Omental Bursa

The omental bursa, or lesser sac, is the portion of the peritoneal cavity behind the stomach and the lesser omentum (a double-layered peritoneal structure connecting the lesser curvature of the stomach

and the proximal part of the duodenum to the liver). The omental bursa communicates with the greater sac via the omental (epiploic) foramen, located posterior to the free edge of the lesser omentum.

Fig. 14.8 The lesser omentum

Anterior view with liver retracted superiorly. The arrow points to the omental foramen, the opening into the omental bursa, posterior to the lesser omentum.

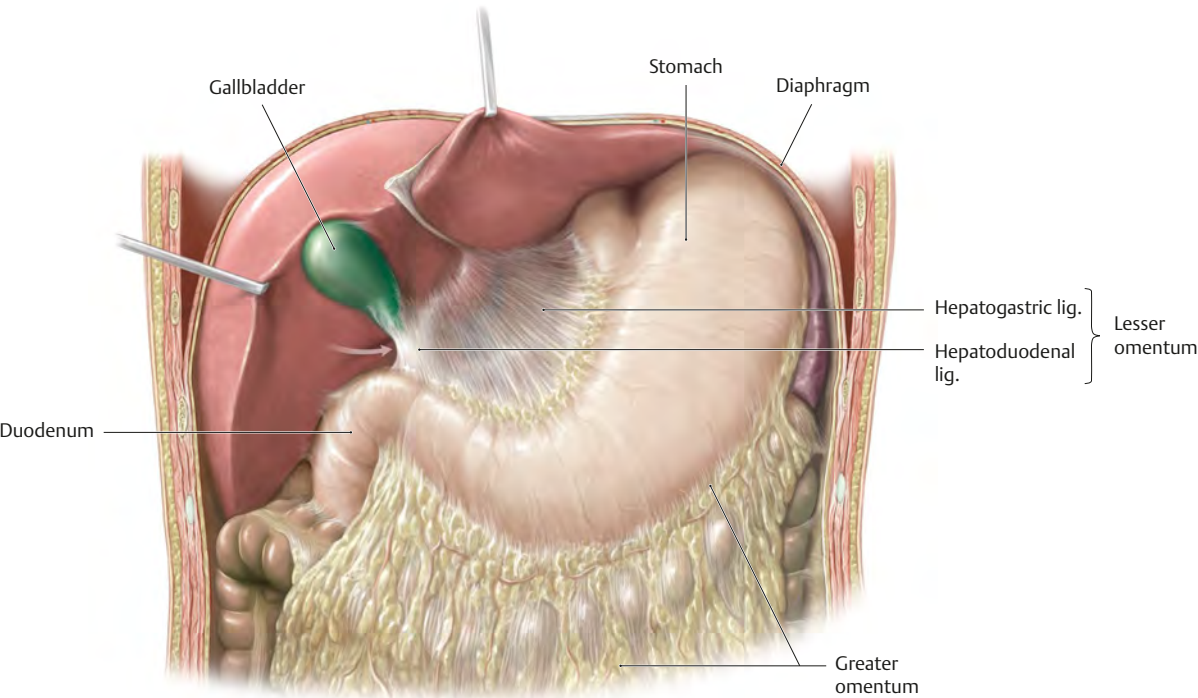


Fig. 14.9 Omental bursa in situ

Anterior view. *Divided:* Gastrocolic ligament. *Retracted:* Liver. *Reflected:* Stomach.

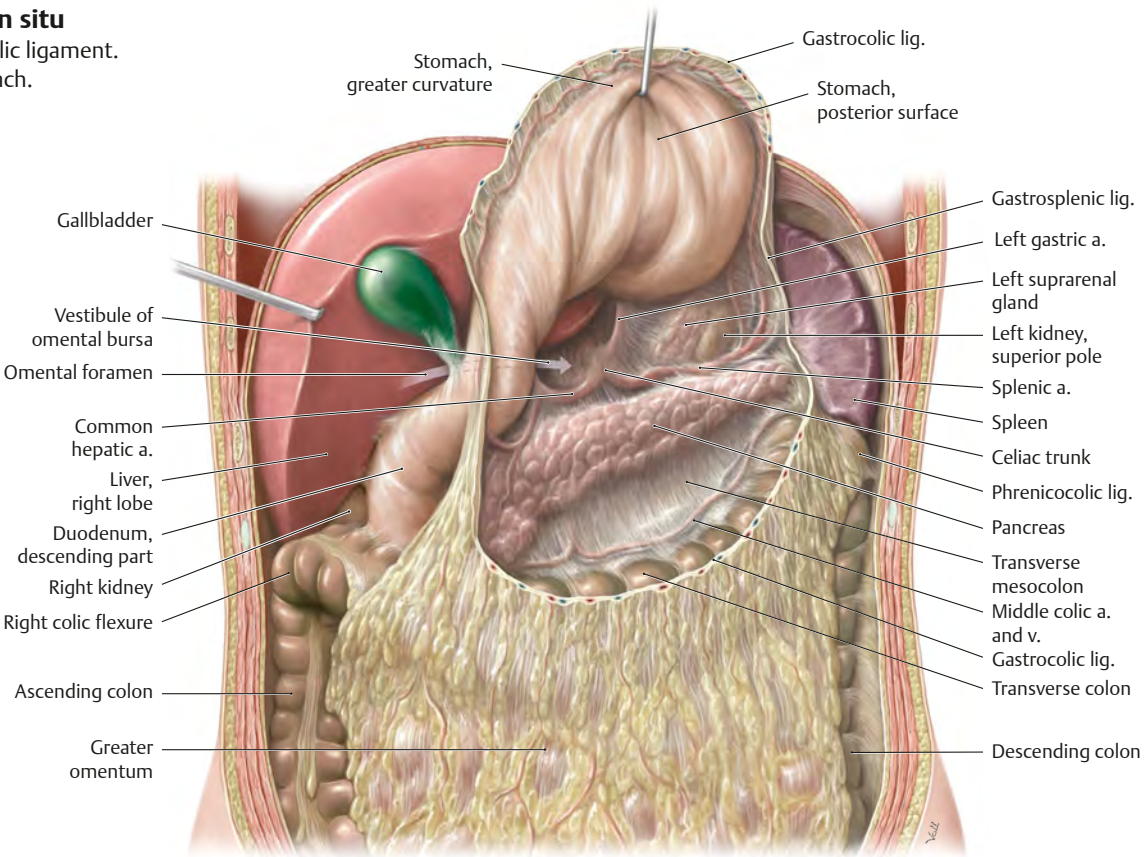


Fig. 14.10 Location of the omental bursa
Transverse section, inferior view.

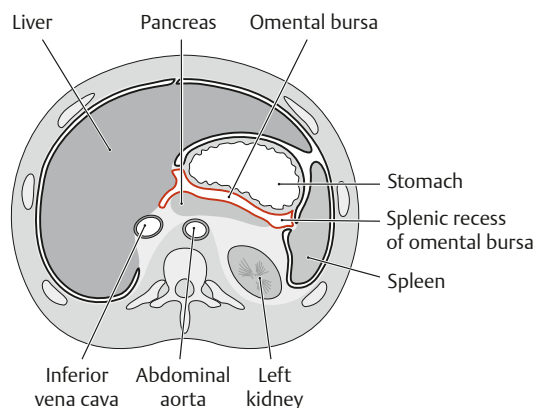
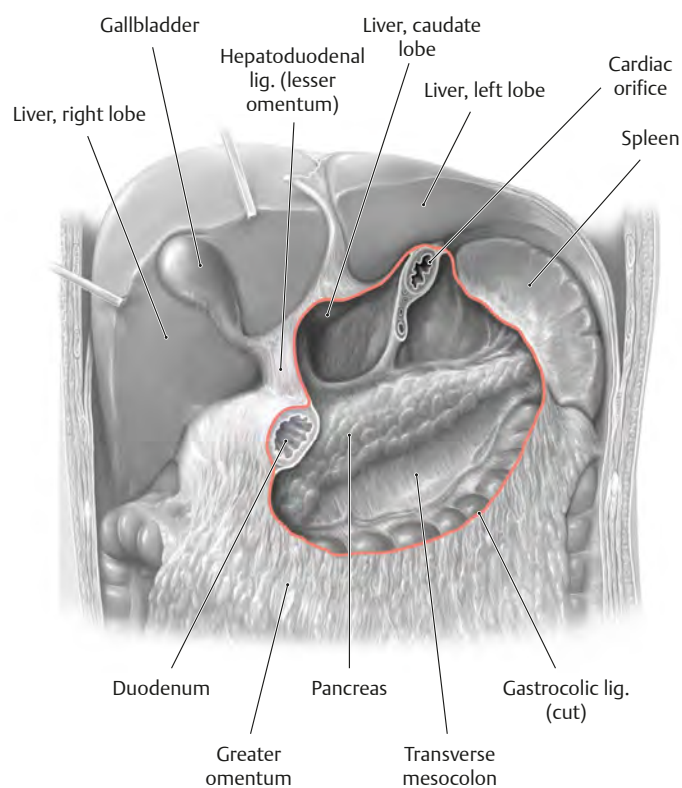
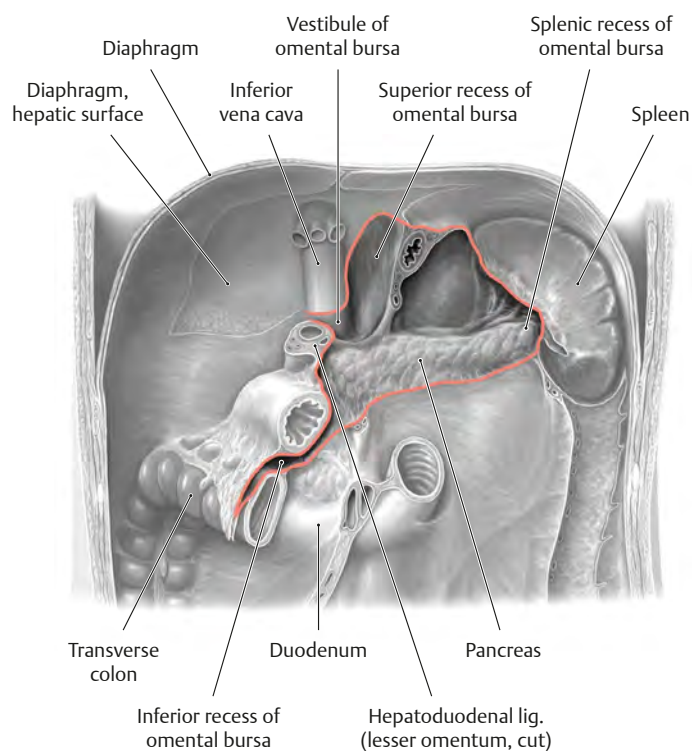


Fig. 14.11 Boundaries and walls of the omental bursa (lesser sac)
Anterior view.



A Boundaries of the omental bursa (lesser sac).



B Posterior wall of the omental bursa (lesser sac).

Table 14.3 Boundaries of the omental bursa

Direction	Boundary	Recess
Anterior	Lesser omentum, gastrocolic lig.	—
Inferior	Transverse mesocolon	Inferior recess
Superior	Liver (with caudate lobe)	Superior recess
Posterior	Pancreas, aorta (abdominal part), celiac trunk, splenic a. and v., gastrosplenic fold, left suprarenal gland, left kidney (superior pole)	—
Right	Liver, duodenal bulb	—
Left	Spleen, gastrosplenic lig.	Splenic recess

Table 14.4 Boundaries of the omental foramen

The communication between the greater sac and lesser sac (omental bursa) is the omental (epiploic) foramen (see arrow in Fig. 14.9).	
Direction	Boundary
Anterior	Hepatoduodenal lig. with the portal v., proper hepatic a., and bile duct
Inferior	Duodenum (superior part)
Posterior	Inferior vena cava, diaphragm (right crus)
Superior	Liver (caudate lobe)

Mesenteries & Posterior Abdominal Wall

Fig. 14.12 Mesenteric attachments of intraperitoneal organs

Anterior view. *Removed:* Stomach, jejunum and ileum, and transverse and sigmoid colons. *Retracted:* Liver.

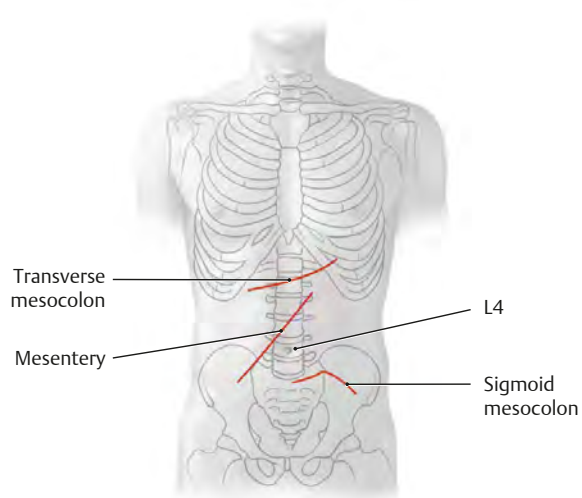
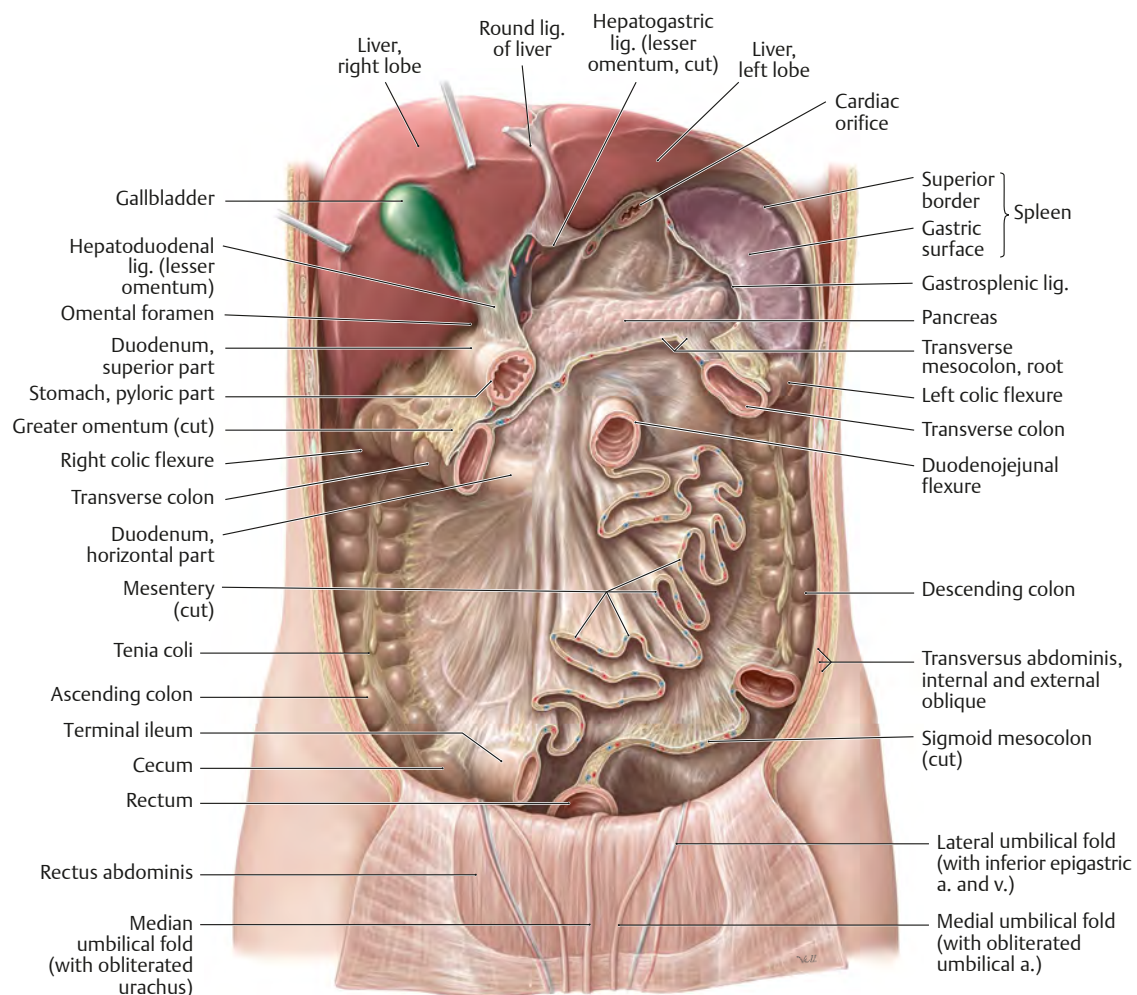
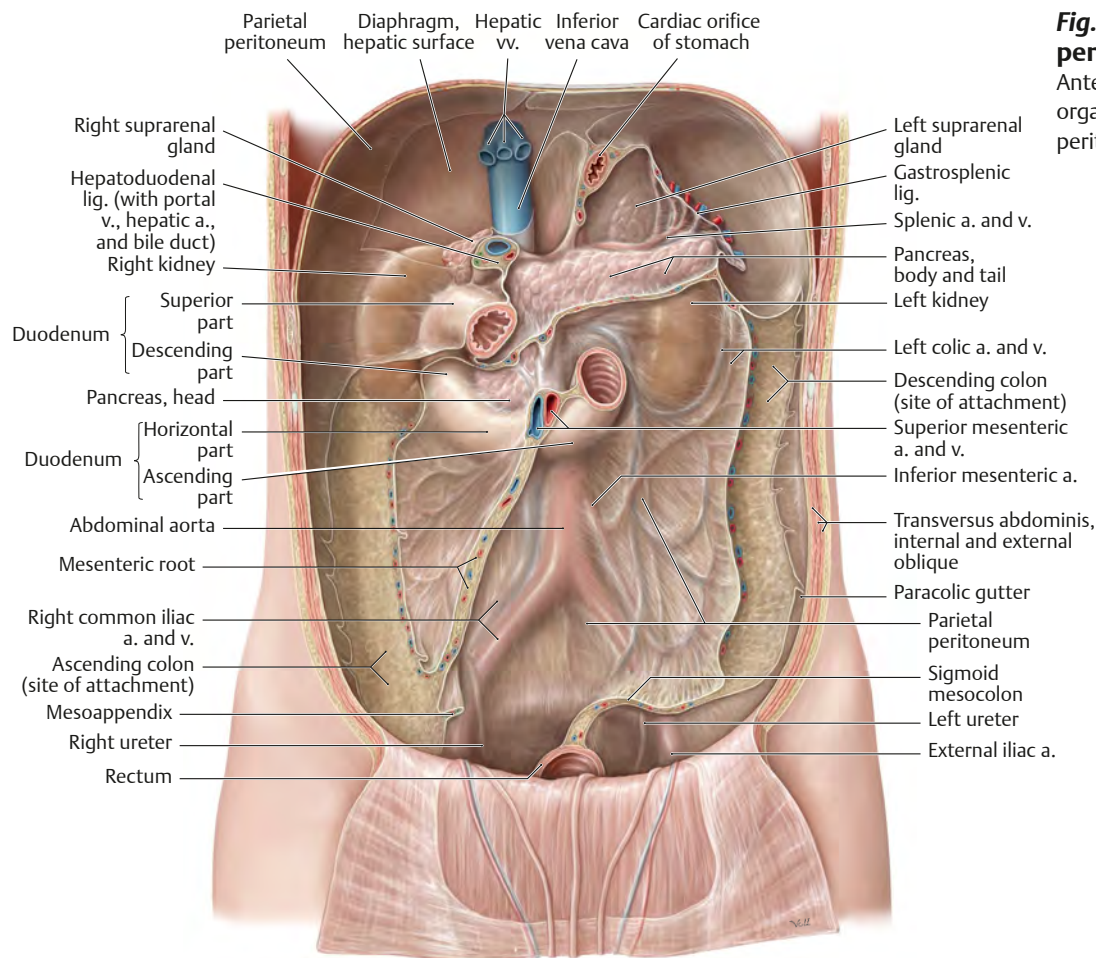


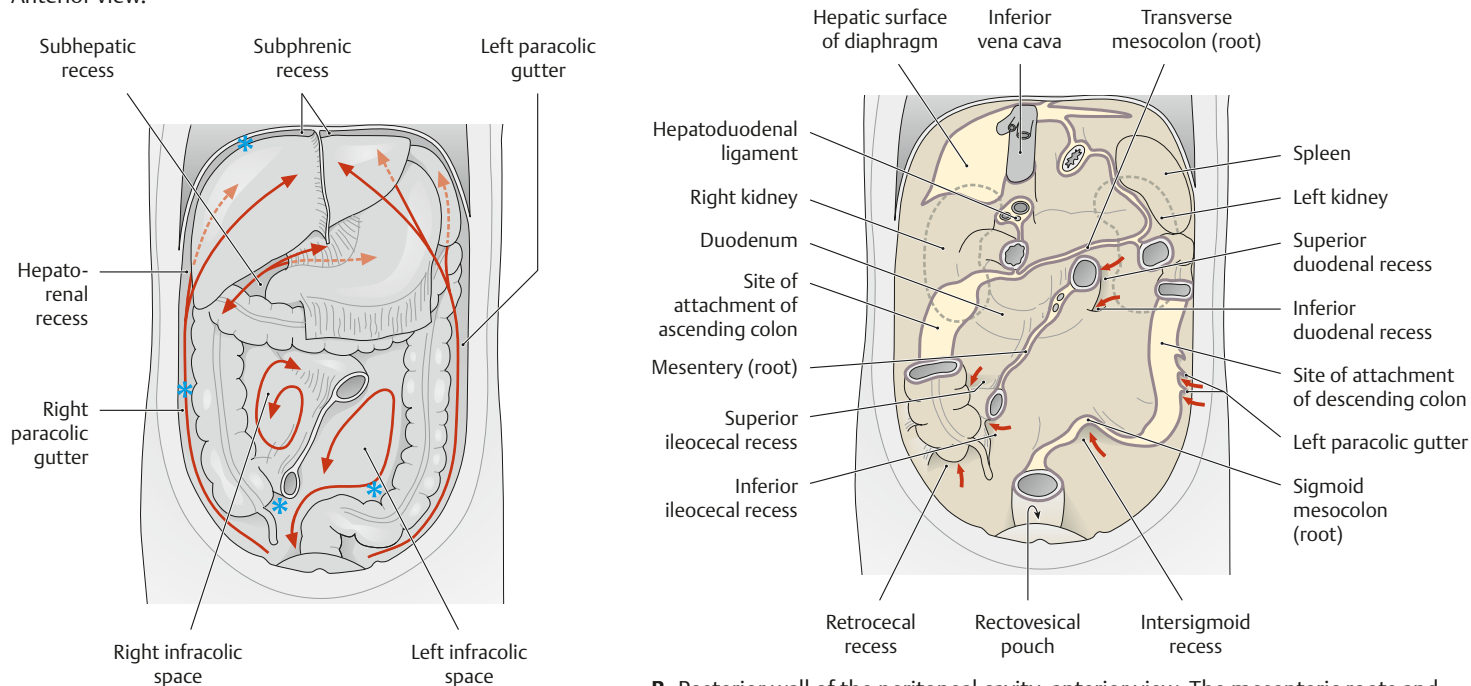
Fig. 14.13 Location of mesenteric sites of connection to the abdominal wall

Fig. 14.14 Posterior wall of the peritoneal cavity

Anterior view. *Removed:* All intraperitoneal organs. *Revealed:* Structures of the retro-peritoneum (see Table 14.2 and p. 250).

**Fig. 14.15 Drainage spaces and recesses within the peritoneal cavity**

Anterior view.

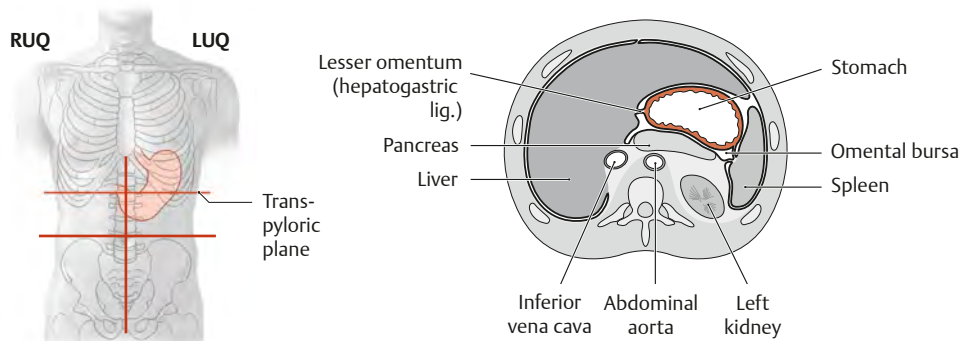


A Anterior view with the greater omentum and small intestine removed; preferred metastatic sites (see blue stars).

B Posterior wall of the peritoneal cavity, anterior view. The mesenteric roots and sites of organ attachment create partially bounded spaces (recesses or sulci) where peritoneal fluid can flow freely.

15 Internal Organs Stomach

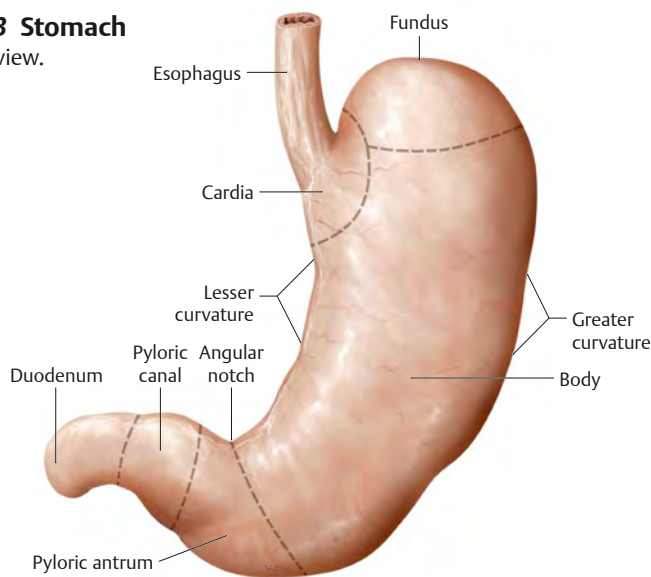
Fig. 15.1 Stomach: Location



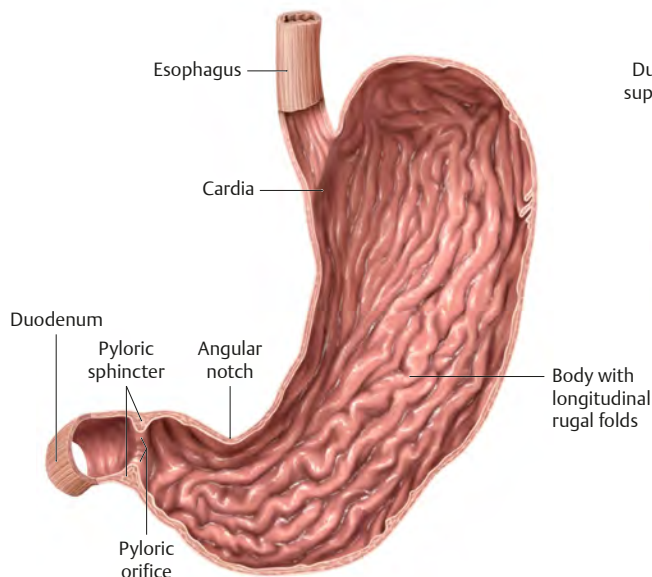
A Anterior view.

B Transverse section, inferior view.

Fig. 15.3 Stomach
Anterior view.

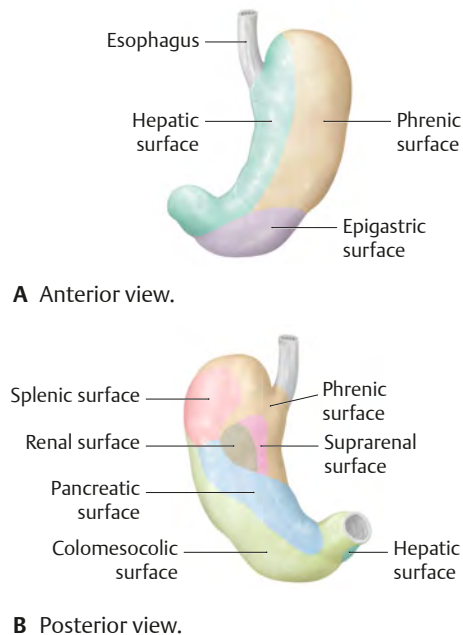


A Anterior wall.

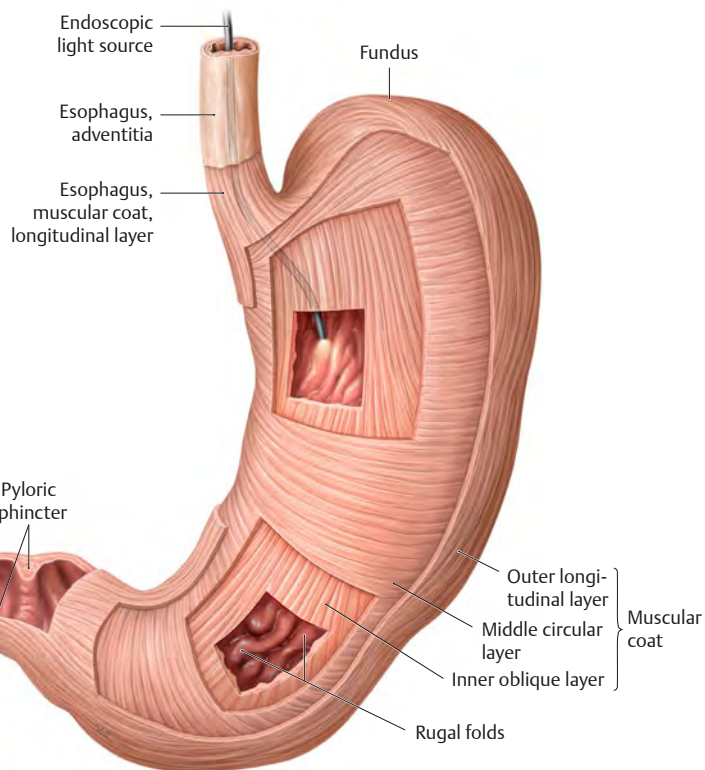


C Interior. Removed: Anterior wall.

Fig. 15.2 Relations of the stomach



B Posterior view.



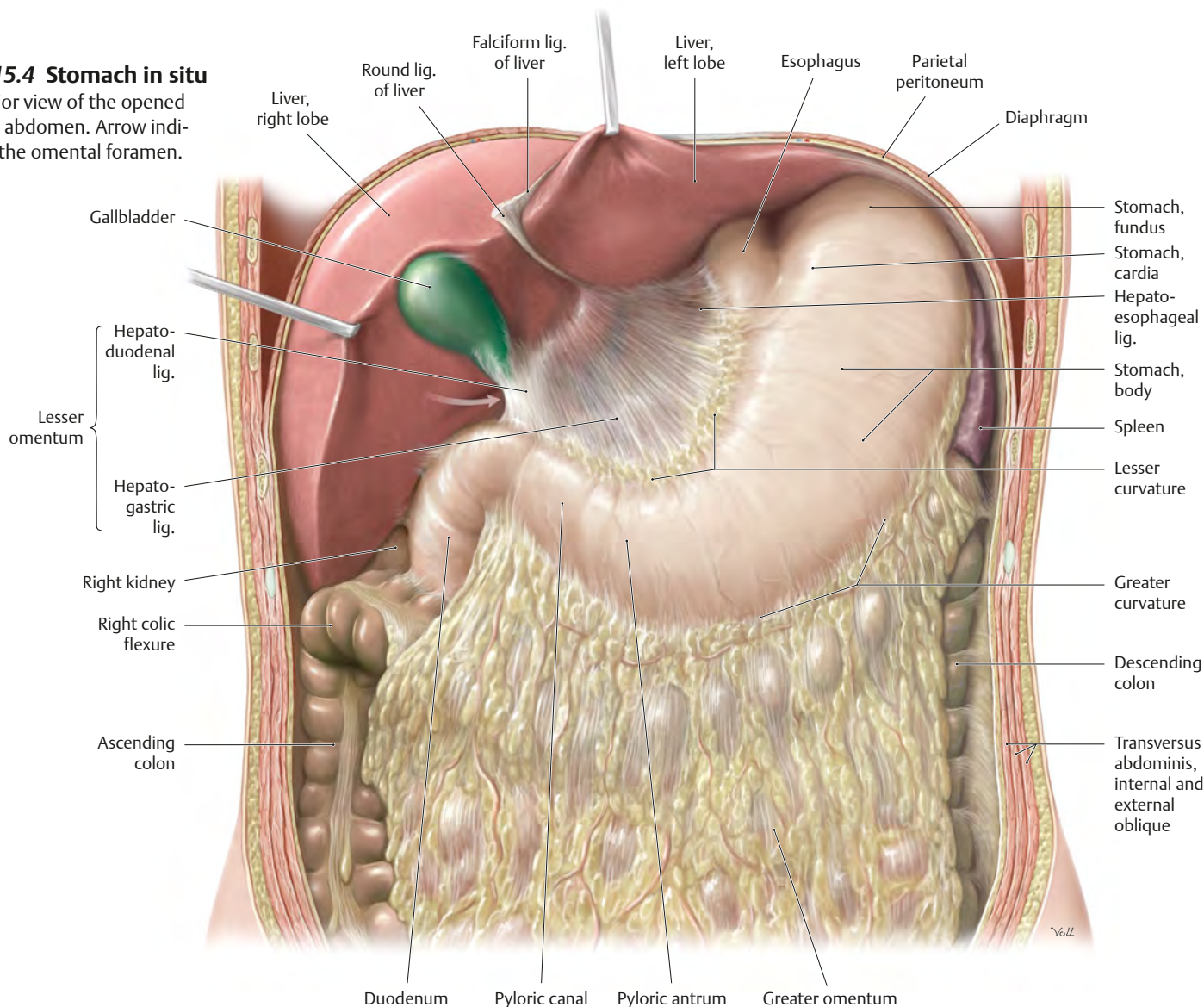
B Muscular layers. Removed: Serosa and subserosa. Windowed: Muscular coat.

The stomach, an intraperitoneal organ, resides primarily in the left upper quadrant. Double layers of peritoneum extend superiorly from its

lesser curvature as the lesser omentum and inferiorly from its greater curvature as the greater omentum.

Fig. 15.4 Stomach in situ

Anterior view of the opened upper abdomen. Arrow indicates the omental foramen.

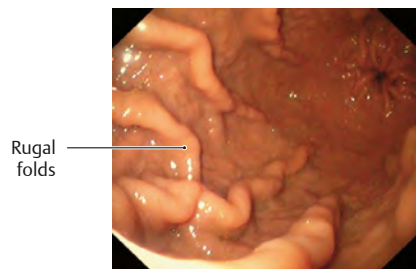


Clinical box 15.1

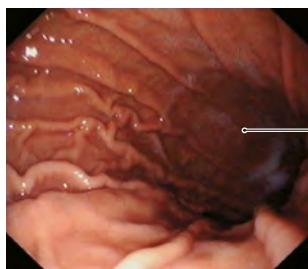
Gastritis and gastric ulcers

Gastritis and gastric ulcers, the two most common diseases of the stomach, are associated with increased acid production and are caused by alcohol, drugs such as aspirin, and the bacterium *Helicobacter pylori*. Symptoms include lessened appetite, pain, and even bleeding, which manifests as

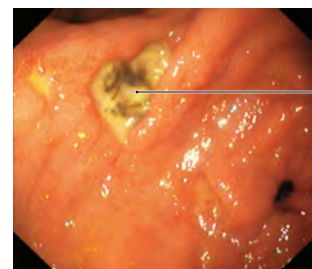
black stool or dark brown material, often described as resembling “coffee grounds,” in vomit. Gastritis is limited to the inner surface of the stomach, whereas gastric ulcers extend into the stomach wall. In these endoscopic images, the gastric ulcer in **C** is covered with fibrin and shows hematin spots.



A Body of normal stomach.



B Normal pyloric antrum.



C Gastric ulcer.

Duodenum

The small intestine consists of the duodenum, jejunum, and ileum. The duodenum is primarily retroperitoneal and is divided into four parts: superior, descending, horizontal, and ascending.

Fig. 15.5 Duodenum: Location

Anterior view.

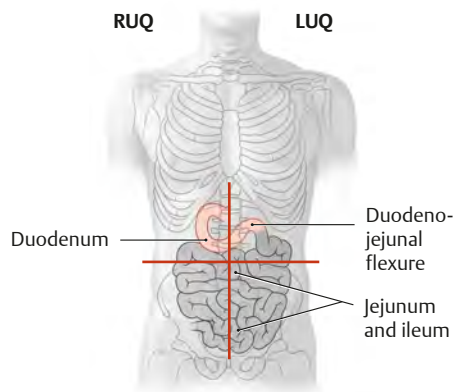


Fig. 15.6 Parts of the duodenum

Anterior view.

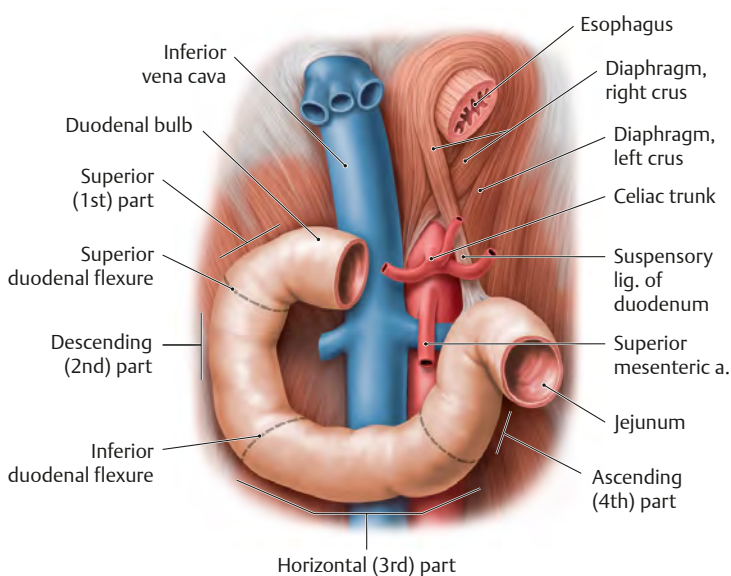


Fig. 15.7 Duodenum

Anterior view with the anterior wall opened.

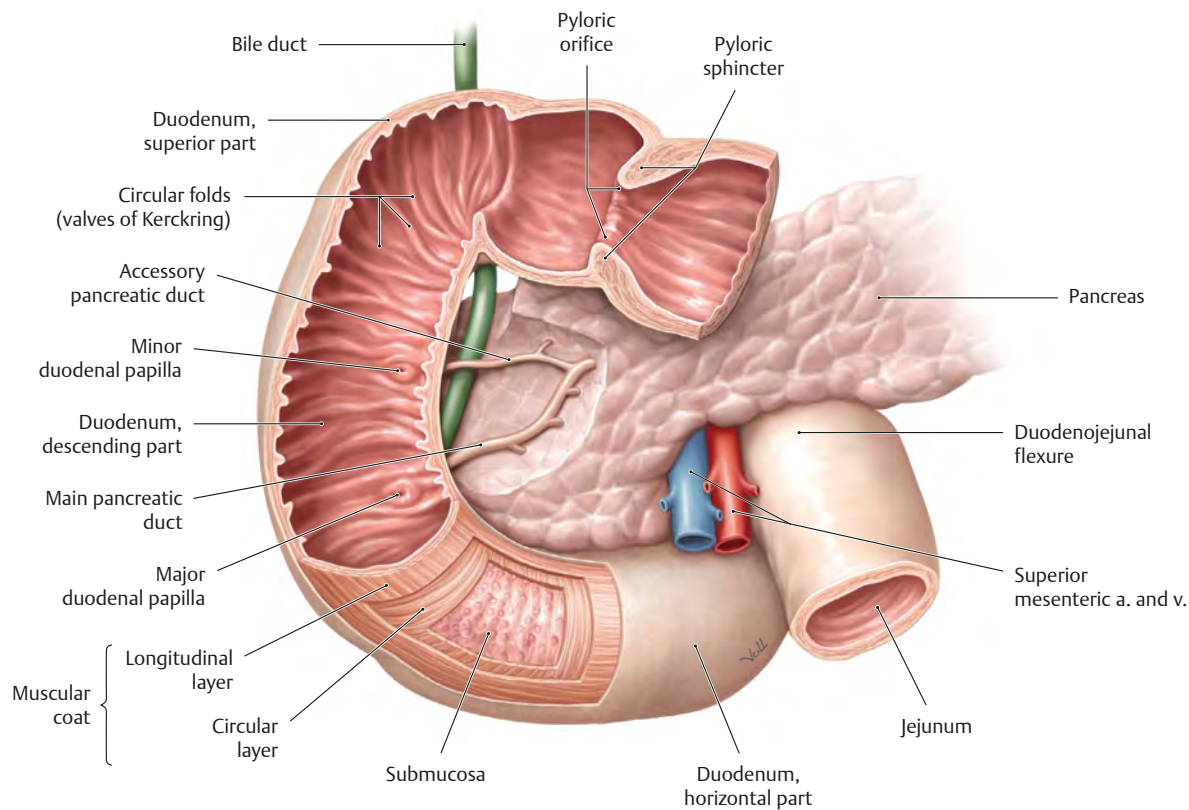
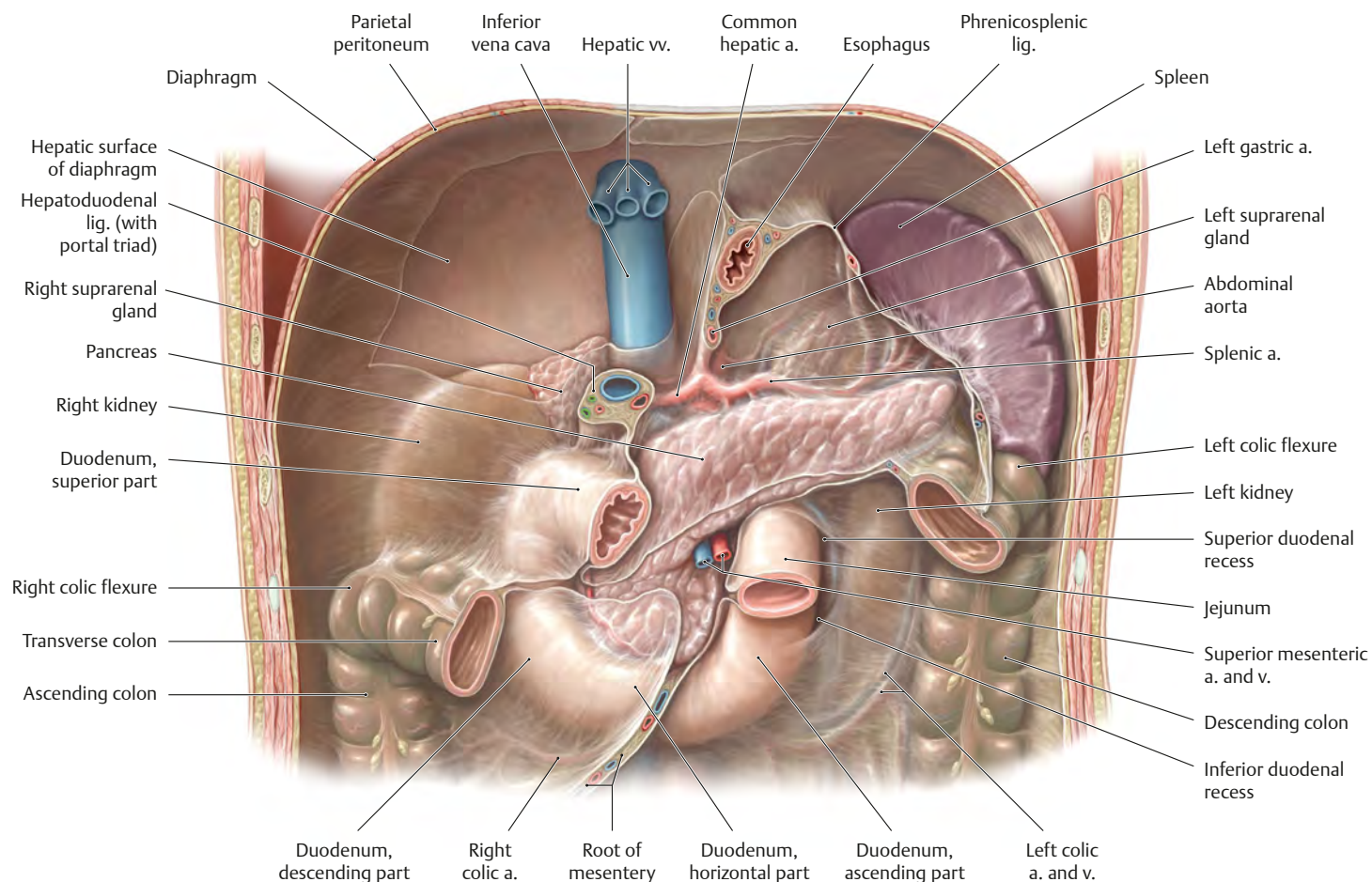


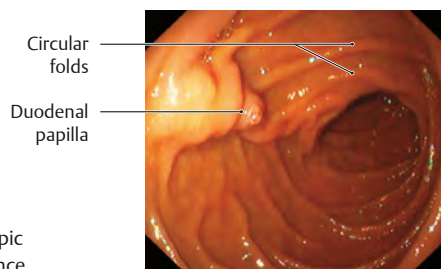
Fig. 15.8 Duodenum in situ

Anterior view. *Removed:* Stomach, liver, small intestine, and large portions of the transverse colon. *Thinned:* Retroperitoneal fat and connective tissue.

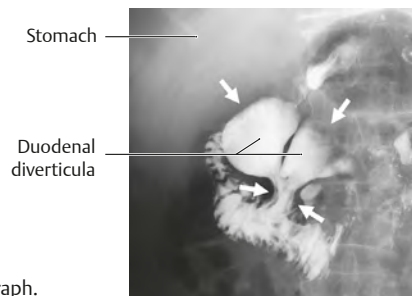
**Clinical box 15.2****Endoscopy of the papillary region**

Two important ducts end at a common exit site in the descending portion of the duodenum: the common bile duct and the pancreatic duct (see Fig. 15.27). These ducts may be examined by X-ray through endoscopic

retrograde cholangiopancreatography (ERCP), in which dye is injected endoscopically into the duodenal papilla. Duodenal diverticula (generally harmless outpouchings) may complicate the procedure.



A Endoscopic appearance.



B Radiograph.

Jejunum & Ileum

Fig. 15.9 Jejunum and ileum: Location

Anterior view. The intraperitoneal jejunum and ileum are enclosed by the mesentery proper.

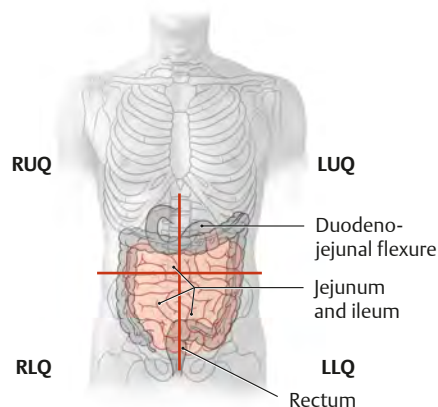


Fig. 15.10 Mucosal appearance of the jejunum and ileum

Macroscopic views of the longitudinally opened small intestine.

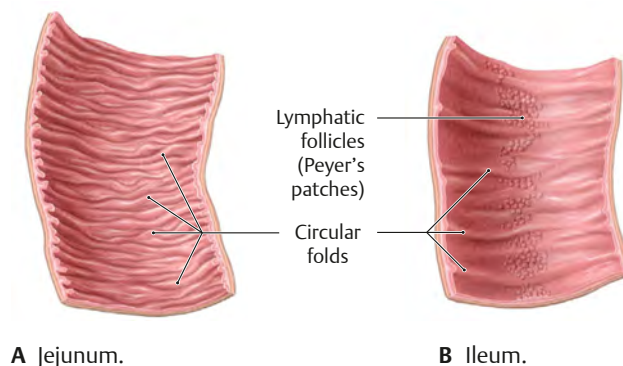
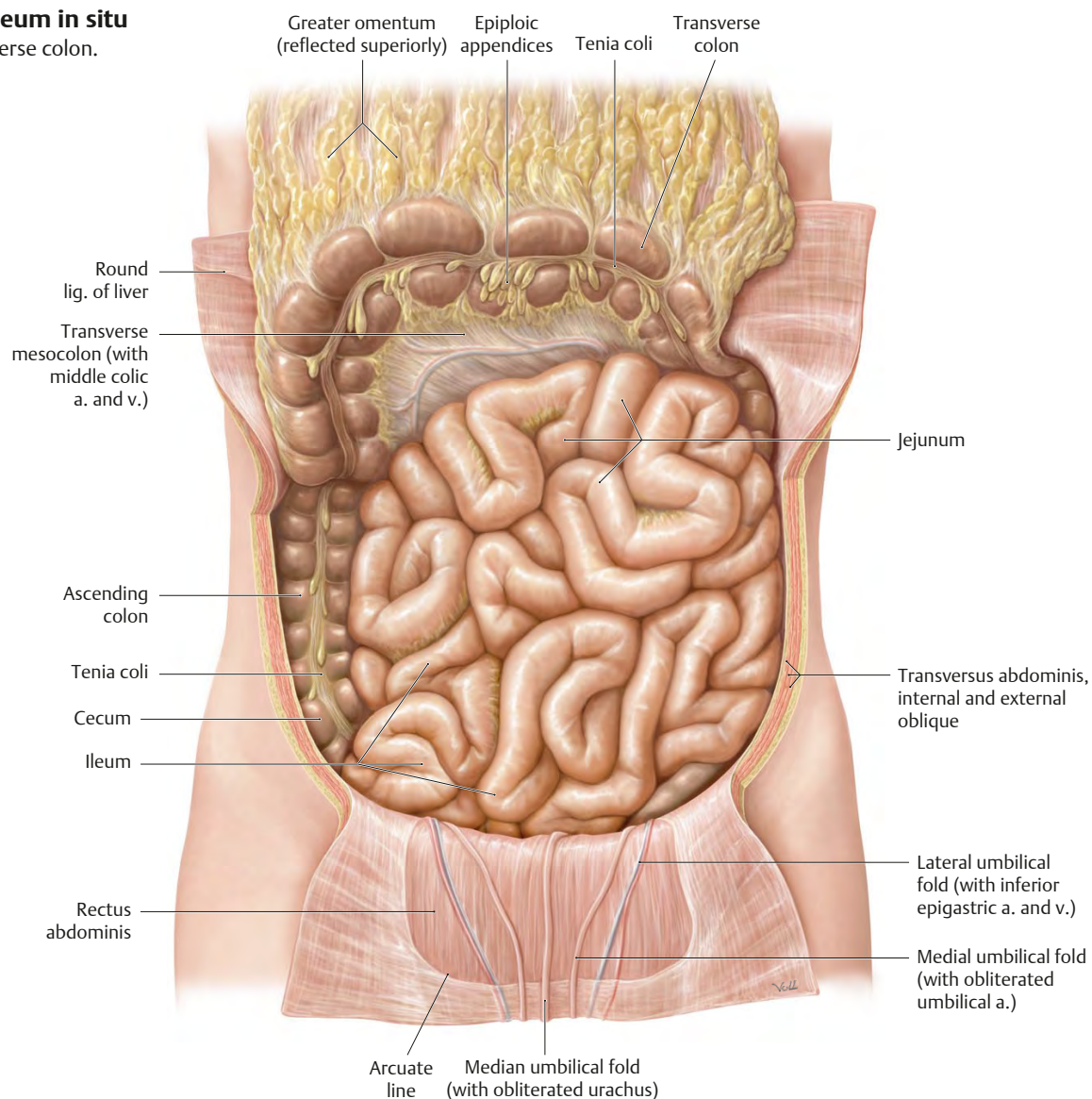


Fig. 15.11 Jejunum and ileum in situ

Anterior view. *Reflected:* Transverse colon.

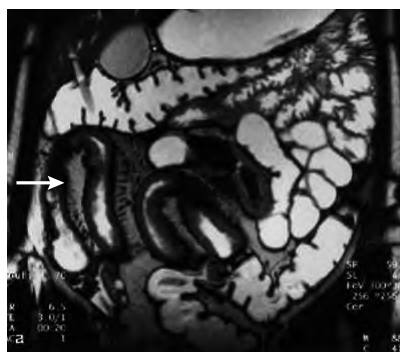




Clinical box 15.3

Crohn's disease

Crohn's disease, a chronic inflammation of the digestive tract, occurs most often in the terminal ileum (30% of cases). Patients are generally young and suffer from abdominal pain, nausea, elevated body temperature, and diarrhea. Initially, these symptoms can be confused with appendicitis. Complications of the chronic inflammation in Crohn's disease often lead to fistula formation (seen here in figure B as an abnormal passage between two gastrointestinal regions).



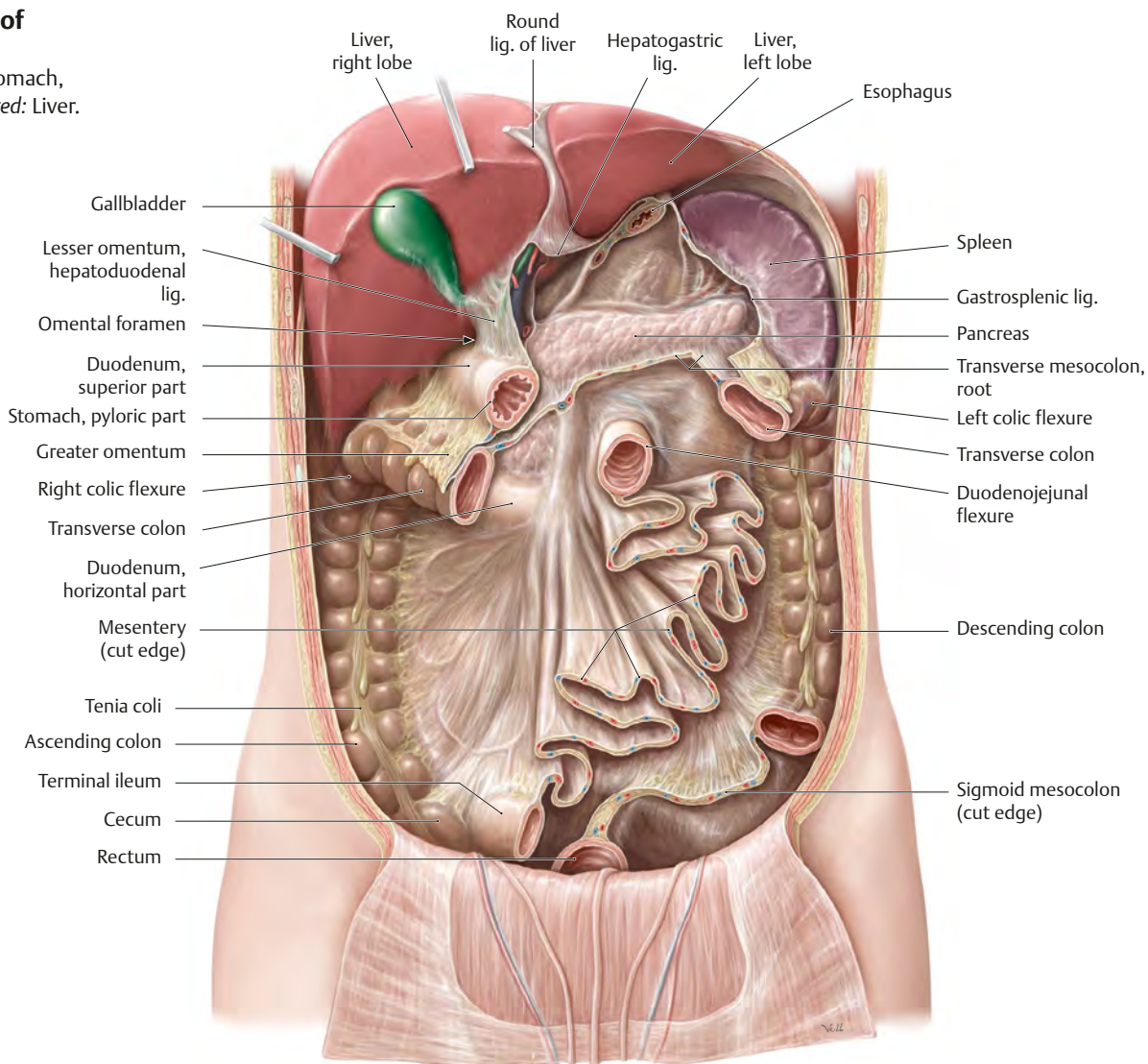
A MRI showing thickened wall of terminal ileum. (arrow).



B Double-contrast radiograph, showing ileorectal fistula (arrow).

Fig. 15.12 Mesentery of the small intestine

Anterior view. *Removed:* Stomach, jejunum, and ileum. *Reflected:* Liver.



Cecum, Appendix & Colon

The ascending and descending colon are normally secondarily retroperitoneal, but are sometimes suspended by a short mesentery from the posterior abdominal wall. *Note:* In the clinical setting, the left colic

flexure is often referred to as the splenic flexure and the right colic flexure, as the hepatic flexure.

Fig. 15.13 Large intestine:

Location

Anterior view.

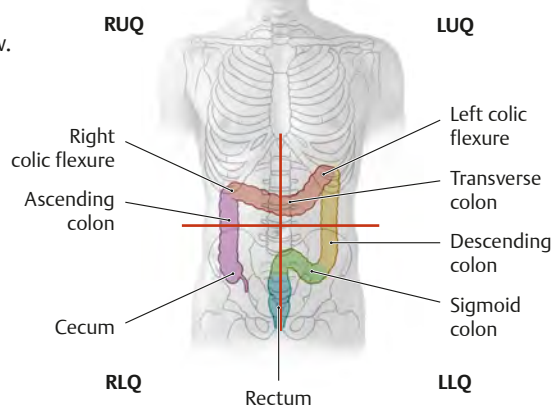


Fig. 15.14 Ileocecal orifice

Anterior view of longitudinal coronal section.

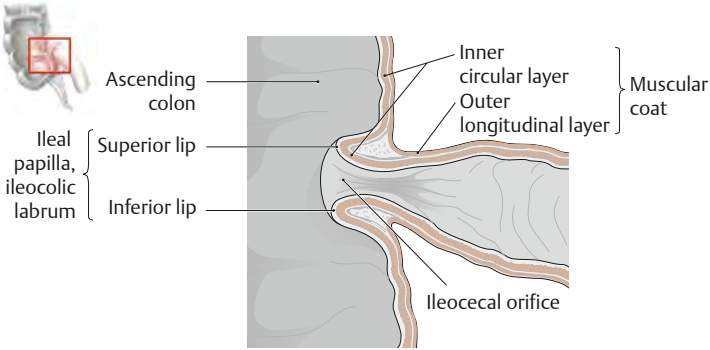


Fig. 15.15 Large intestine

Anterior view.

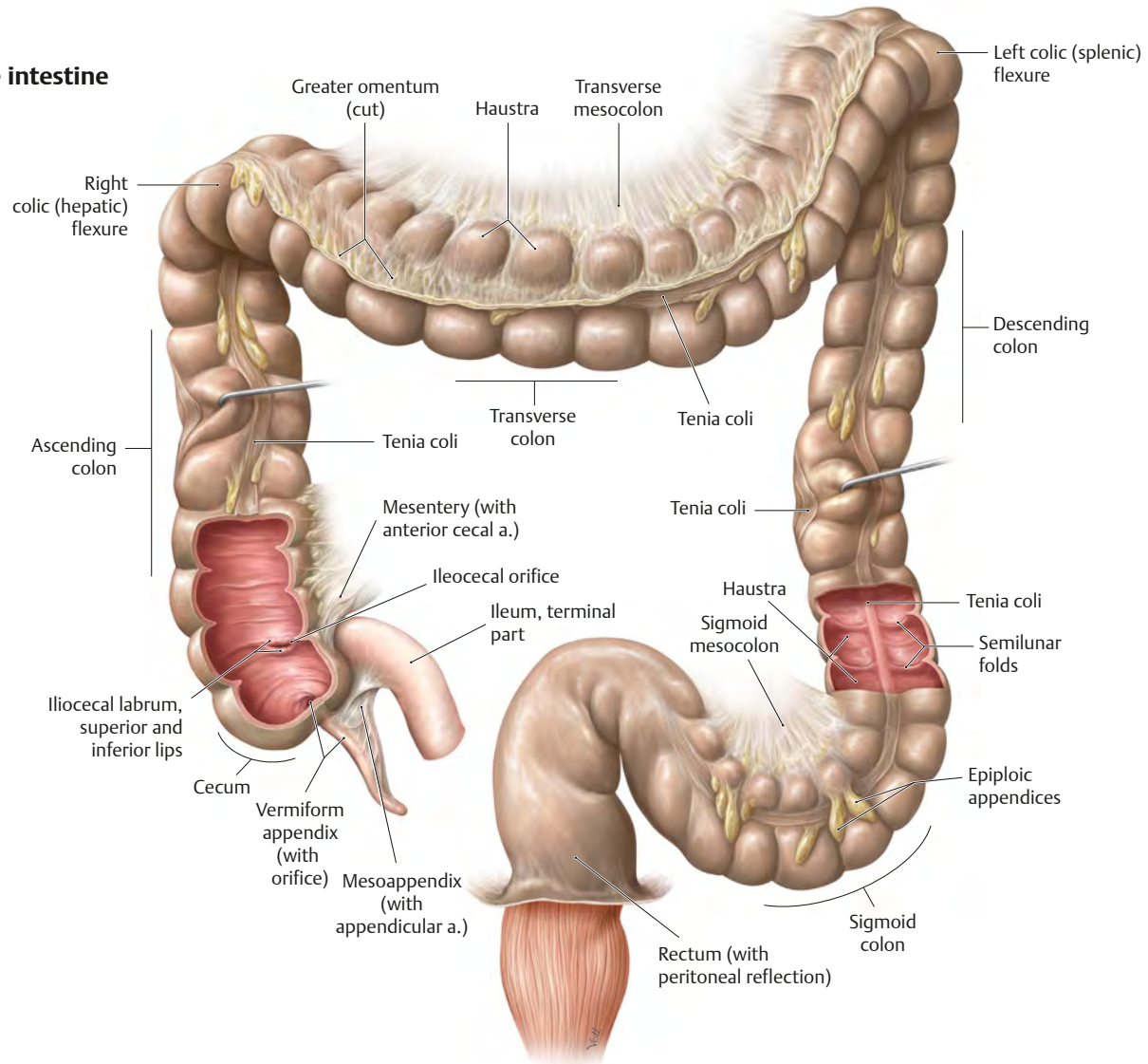
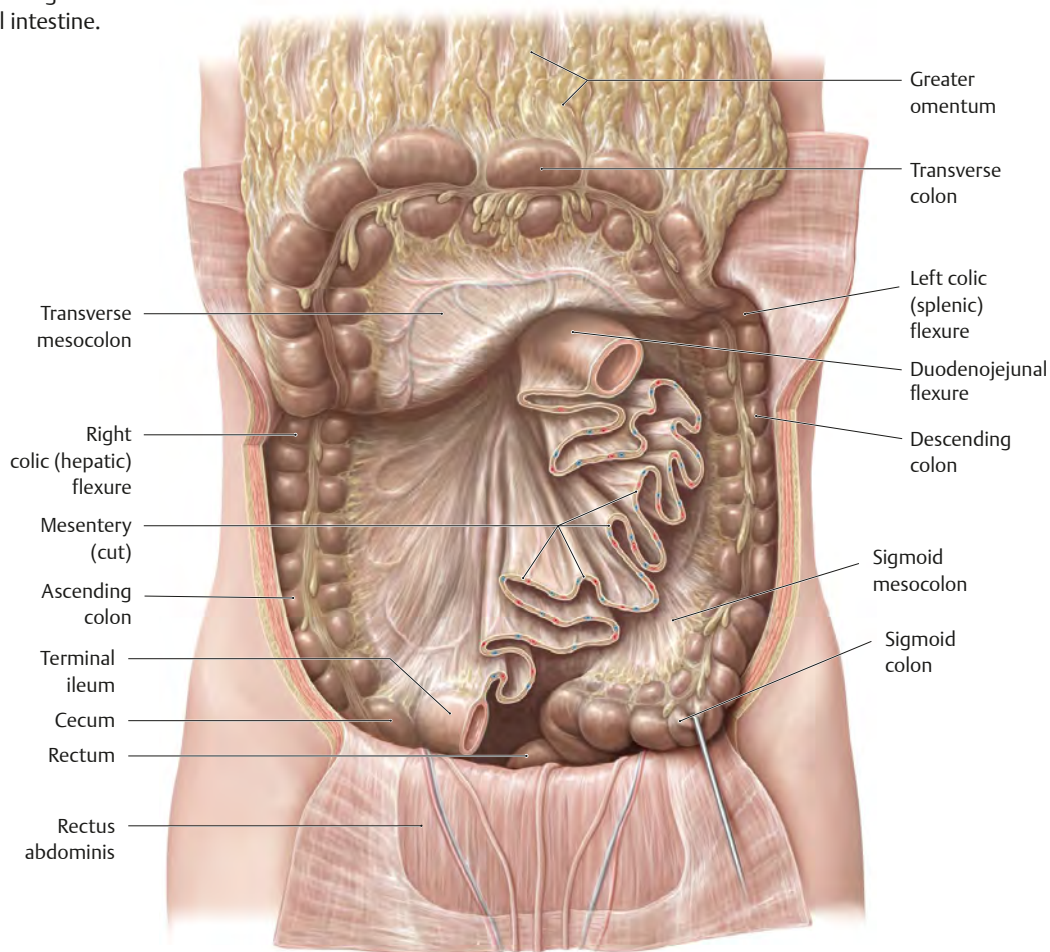
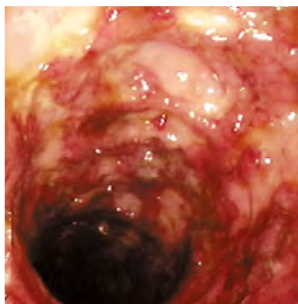


Fig. 15.16 Large intestine in situ

Anterior view. *Reflected:* Transverse colon and greater omentum. *Removed:* Intraperitoneal small intestine.

**Clinical box 15.4****Colitis**

Ulcerative colitis is a chronic inflammation of the large intestine, often starting in the rectum. Typical symptoms include diarrhea (sometimes with blood), pain, weight loss, and inflammation of other organs. Patients are also at higher risk for colorectal carcinomas.



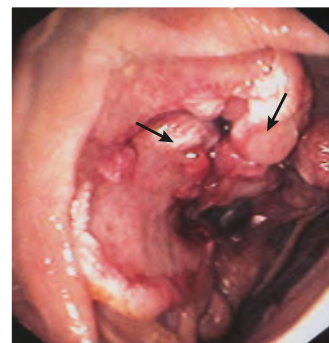
A Colonoscopy of ulcerative colitis.



B Early-phase colitis. Double-contrast radiograph, anterior view.

**Clinical box 15.5****Colon carcinoma**

Malignant tumors of the colon and rectum are among the most frequent solid tumors. More than 90% occur in patients over the age of 50. In early stages, the tumor may be asymptomatic; later symptoms include loss of appetite, changes in bowel movements, and weight loss. Blood in the stools is particularly incriminating, necessitating a thorough examination. Hemorrhoids are not a sufficient explanation for blood in stools unless all other tests (including a colonoscopy) are negative.



Colonoscopy of colon carcinoma. The tumor (*black arrows*) partially blocks the lumen of the colon.

Liver: Overview

Fig. 15.17 Liver: Location

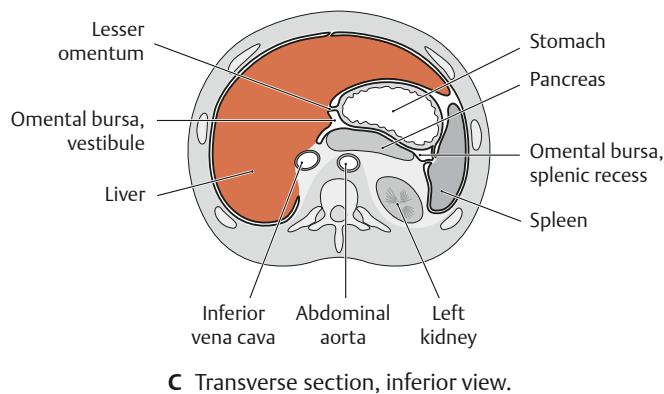
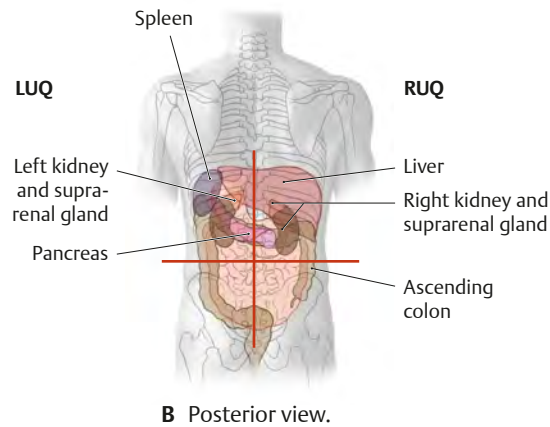
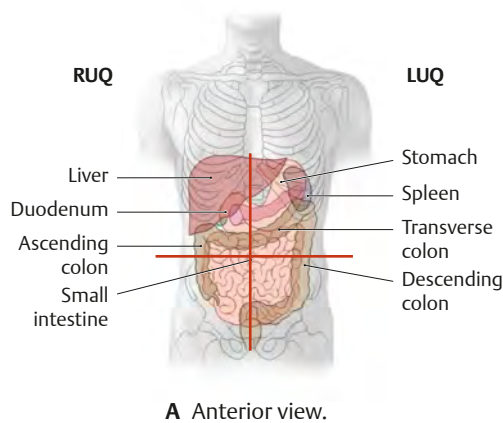


Fig. 15.18 Relations of the liver
Visceral (inferior) surface, inferior view.

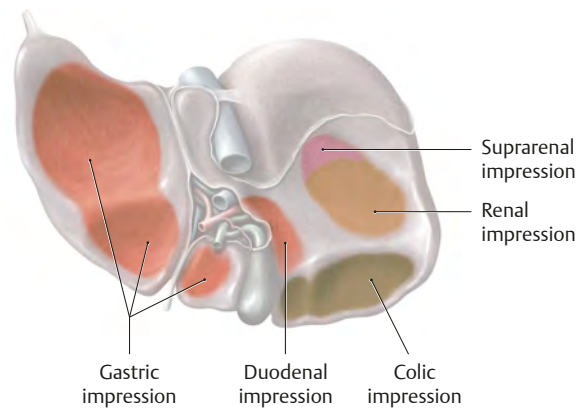


Fig. 15.19 Liver in situ

Anterior view. The liver is intraperitoneal except for its “bare area” (see **Fig. 15.21**); its mesenteries include the falciform, coronary, and triangular ligaments (see **Fig. 15.22**).

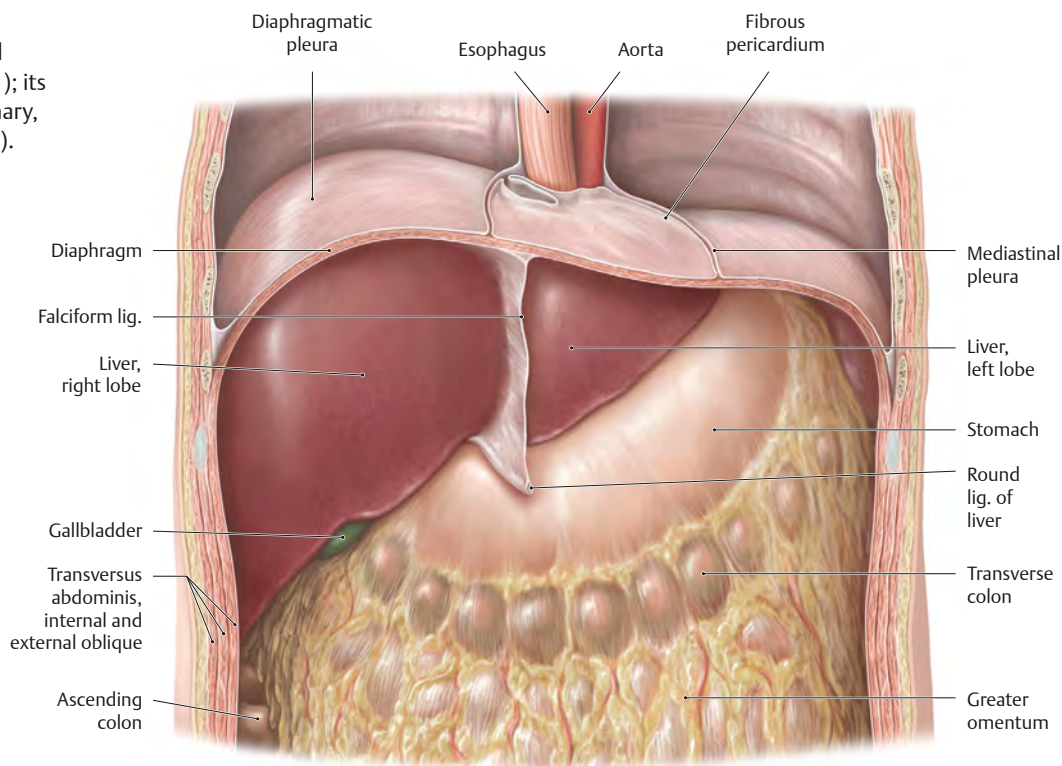
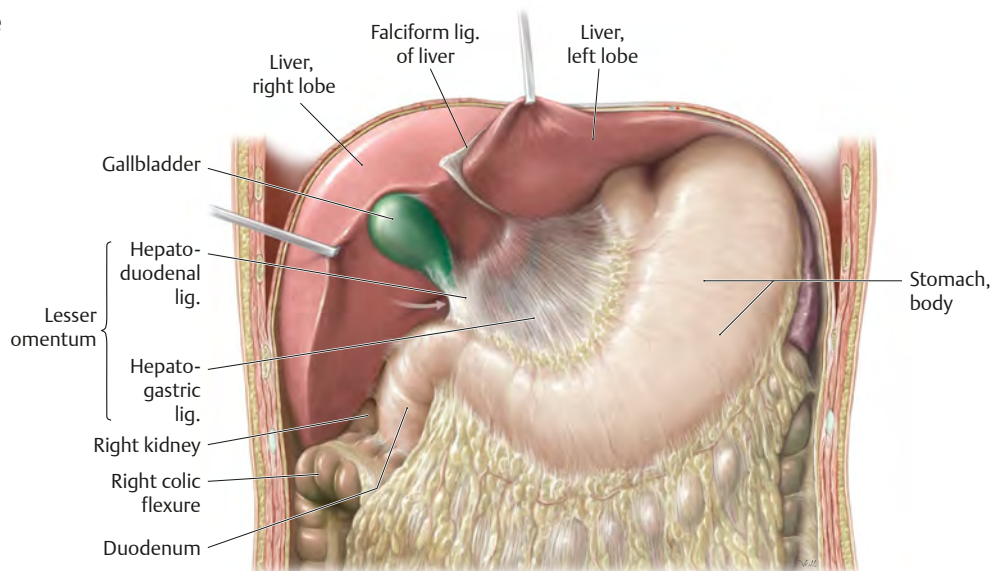
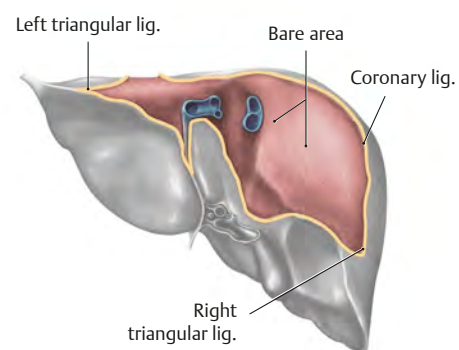
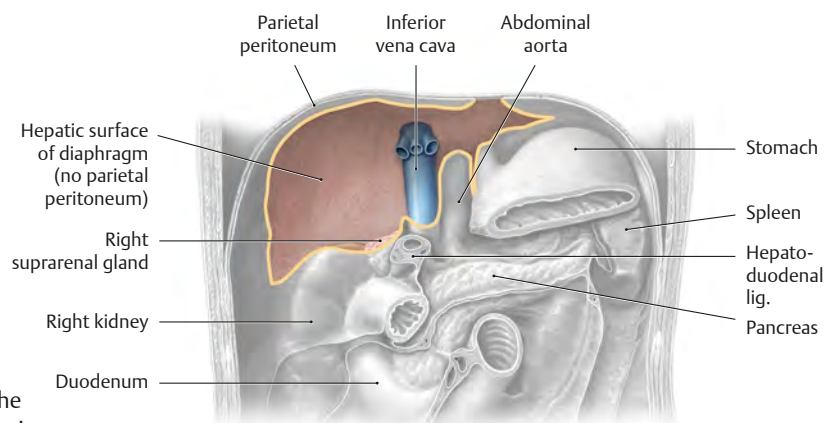


Fig. 15.20 Liver in situ: Inferior surface

The liver is retracted to show the gallbladder on its inferior surface.

**Fig. 15.21 Attachment of liver to diaphragm**

A Diaphragmatic surface of the liver, posterior view.

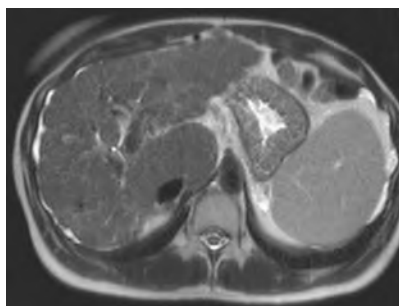


B Hepatic surface of the diaphragm, anterior view.

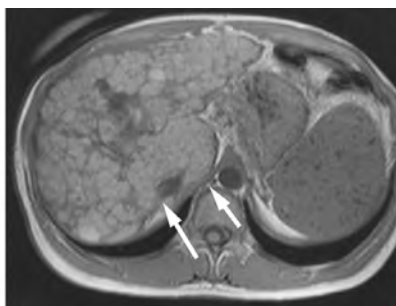
**Clinical box 15.6****Hepatic cirrhosis**

Hepatic cirrhosis is a condition leading to irreversible fibrosis of the liver parenchyma. Alcohol abuse is the leading cause (70% of cases) followed by hepatitis B. Portal hypertension with the development of collateral vessels is a common result arising in approximately 30% of cases.

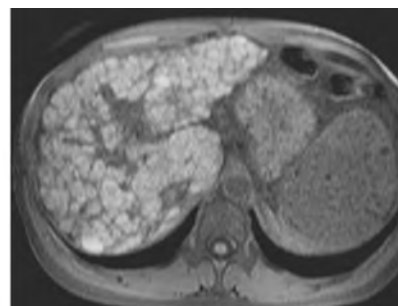
Changes associated with advanced hepatic cirrhosis. All three sequences show multiple regenerating nodules in the liver, creating a nodular surface contour. Only the caudate lobe (**B, arrow**) is less affected by the changes and still shows a relatively normal signal.



A T2W sequence. (Reproduced from Krombach GA, Mahnken AH. Body Imaging: Thorax and Abdomen. New York, NY: Thieme; 2018.)



B T1W sequence. (Reproduced from Krombach GA, Mahnken AH. Body Imaging: Thorax and Abdomen. New York, NY: Thieme; 2018.)



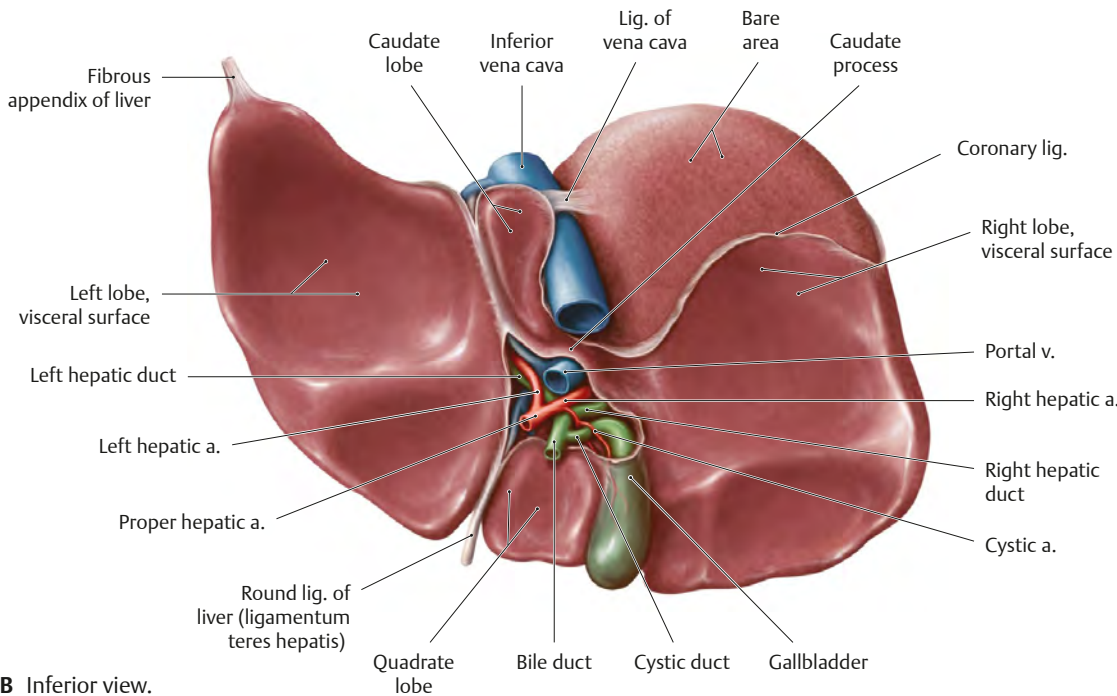
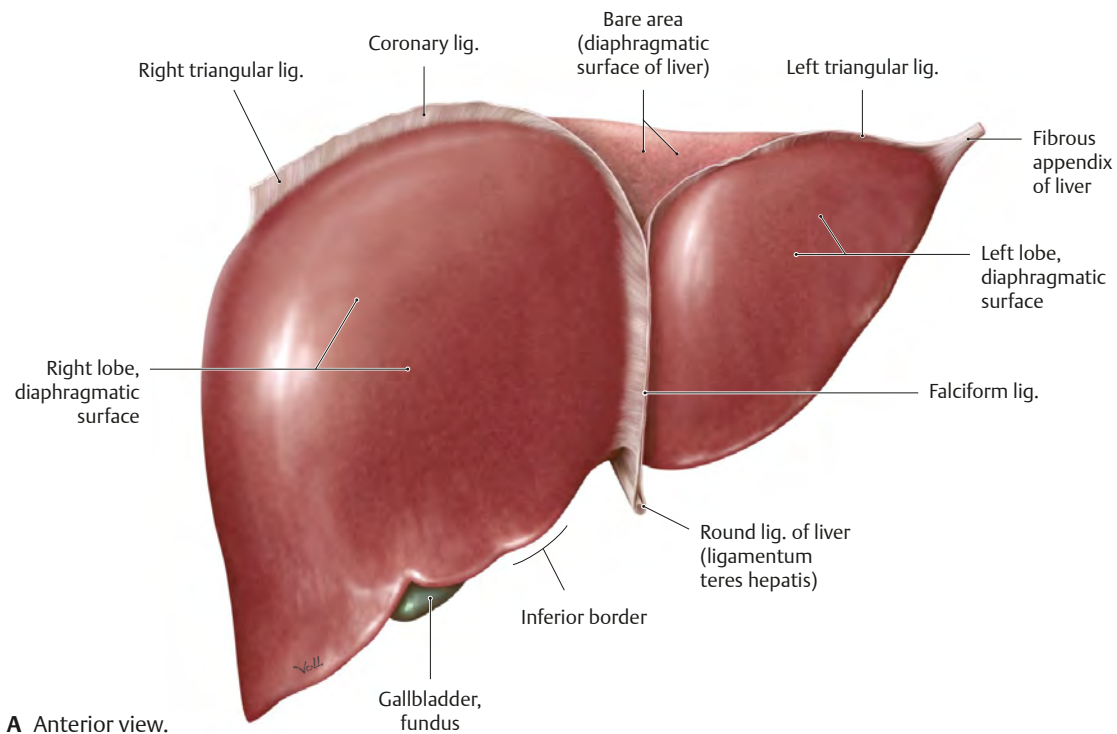
C Fat-suppressed T1W sequence. (Reproduced from Krombach GA, Mahnken AH. Body Imaging: Thorax and Abdomen. New York, NY: Thieme; 2018.)

Liver: Lobes & Segments

Fig. 15.22 Surfaces of the liver

The liver is divided into four lobes by its ligaments: right, left, caudate, and quadrate. The falciform ligament, a double layer of parietal peritoneum that reflects off the anterior abdominal wall and extends to the liver, spreading out over its surface as visceral peritoneum,

divides the liver into right and left anatomical lobes. The round ligament of the liver is found in the free edge of the falciform ligament and is the obliterated umbilical vein, which once extended from the umbilicus to the liver.



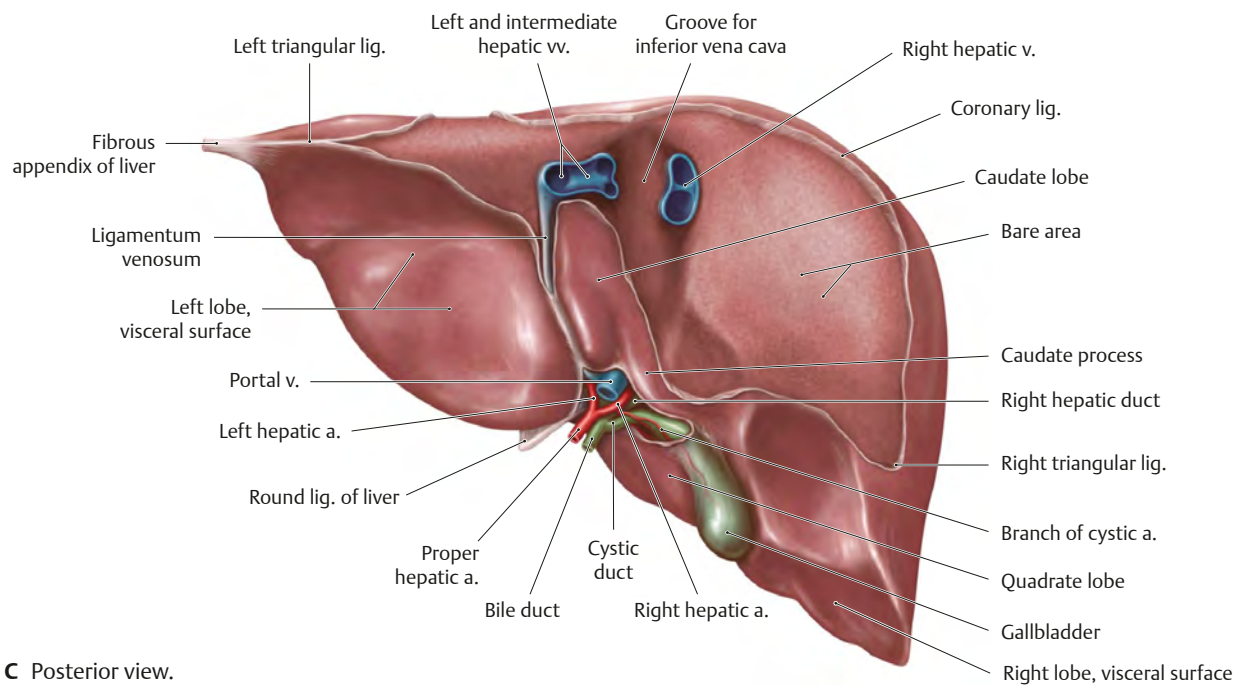


Fig. 15.23 Segmentation of the liver

The liver is divided into functional divisions, which are further divided into segments (see **Table 15.1**). Each segment is served by tertiary branches of the hepatic artery, the portal vein, and the common hepatic duct, which together make up the portal triad.

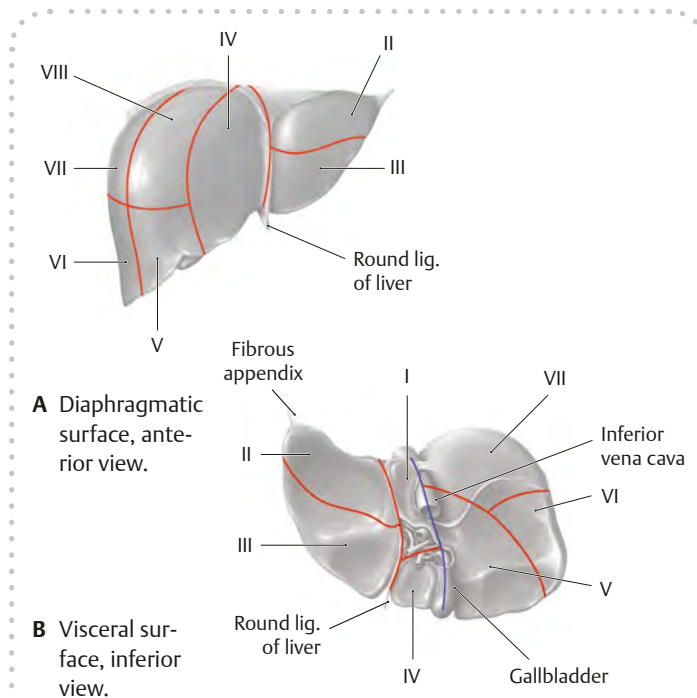
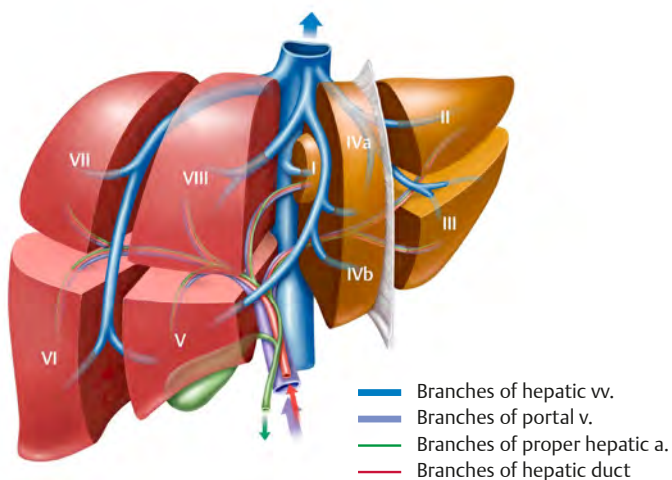


Table 15.1 Hepatic segments

Part	Division	Segment	
Left part	Posterior part	I	Caudate lobe
	Left lateral division	II	Left posterolateral
		III	Left anterolateral
	Left medial division	IV	Left medial
Right part	Right medial division	V	Right anteromedial
		VI	Right anterolateral
	Right lateral division	VII	Right posterolateral
		VIII	Right posteromedial

Gallbladder & Bile Ducts

Fig. 15.24 Gallbladder: Location

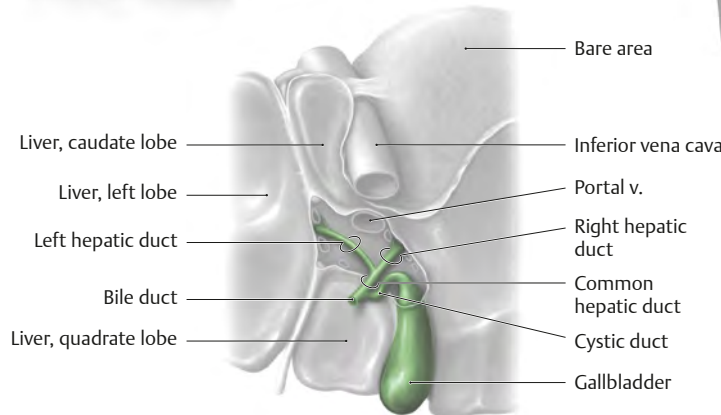
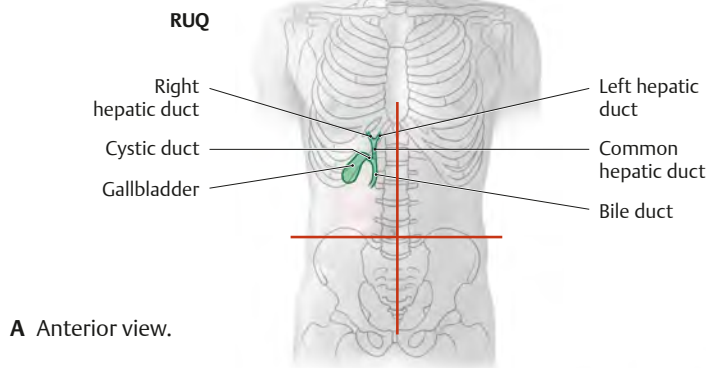


Fig. 15.25 Hepatic bile ducts: Location
Projection onto surface of the liver, anterior view.

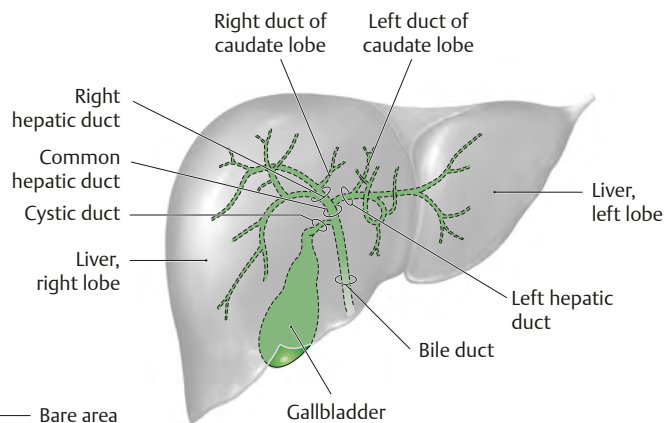


Fig. 15.26 Biliary sphincter system

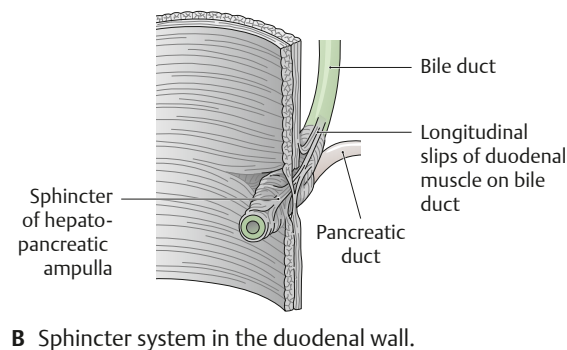
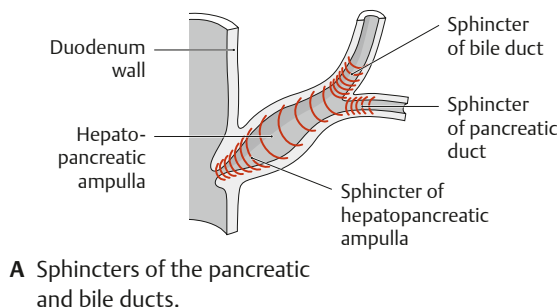


Fig. 15.27 Extrahepatic bile ducts
Anterior view. Opened: Gallbladder and duodenum.

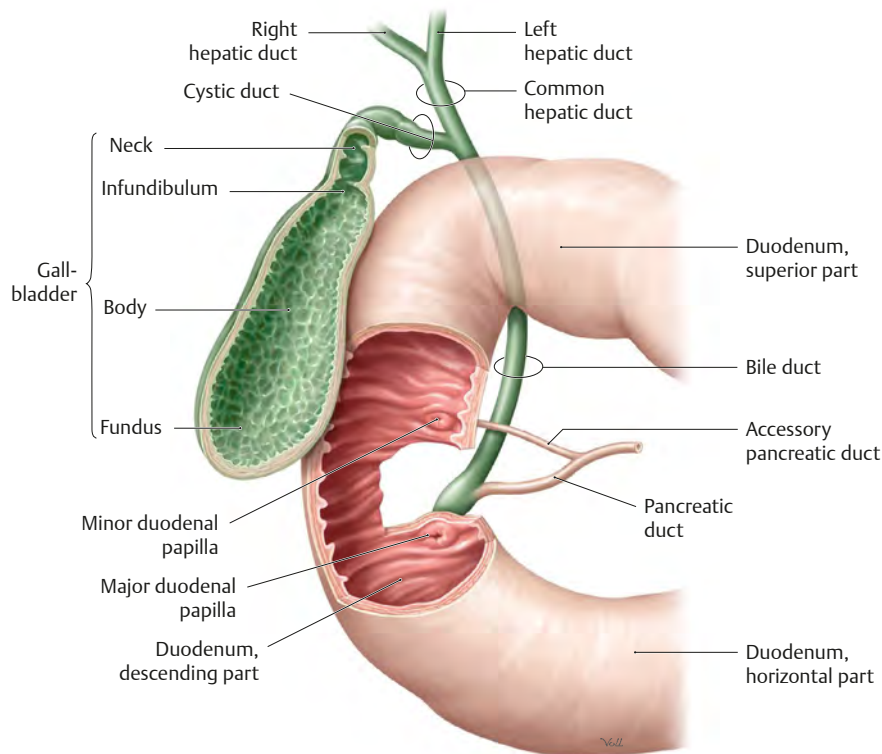
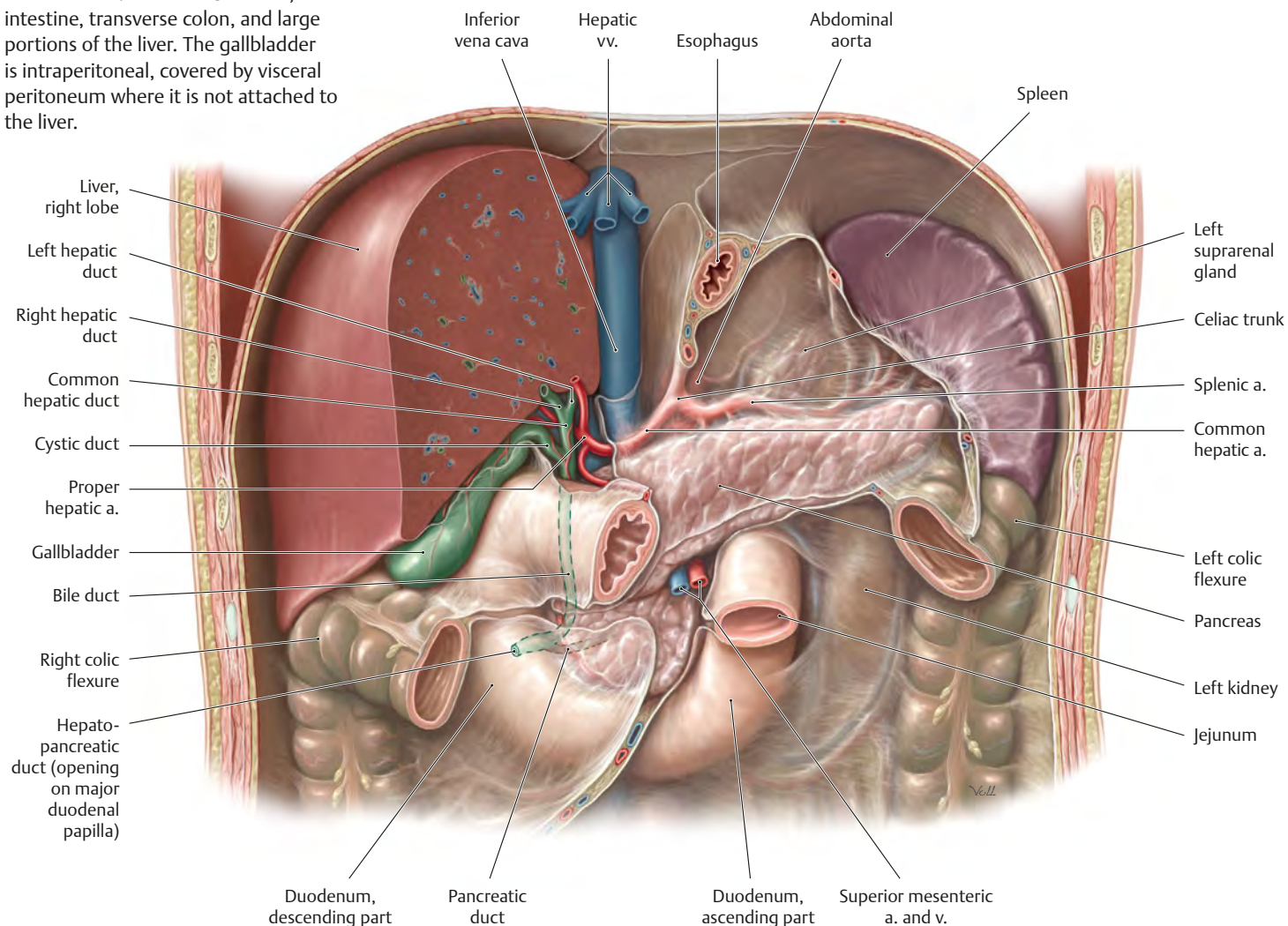
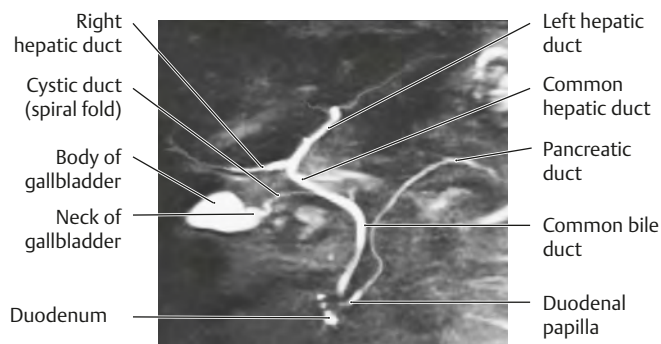


Fig. 15.28 Biliary tract in situ

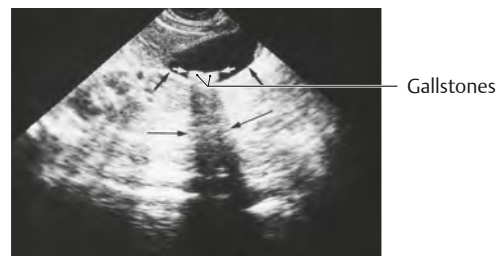
Anterior view. *Removed:* Stomach, small intestine, transverse colon, and large portions of the liver. The gallbladder is intraperitoneal, covered by visceral peritoneum where it is not attached to the liver.

**Fig. 15.29 MR Cholangiopancreatography**

(Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 3rd ed. New York, NY: Thieme; 2007.)

**Clinical box 15.7****Obstruction of the bile duct**

As bile is stored and concentrated in the gallbladder, certain substances, such as cholesterol, may crystallize, resulting in the formation of gallstones. Migration of gallstones into the bile duct causes severe pain (colic). Gallstones may also block the pancreatic duct in the papillary regions, causing highly acute or even life-threatening pancreatitis.



Ultrasound appearance of two gallstones. Black arrows mark the echo-free area behind the stones.

Pancreas & Spleen

Fig. 15.30 Pancreas and spleen: Location

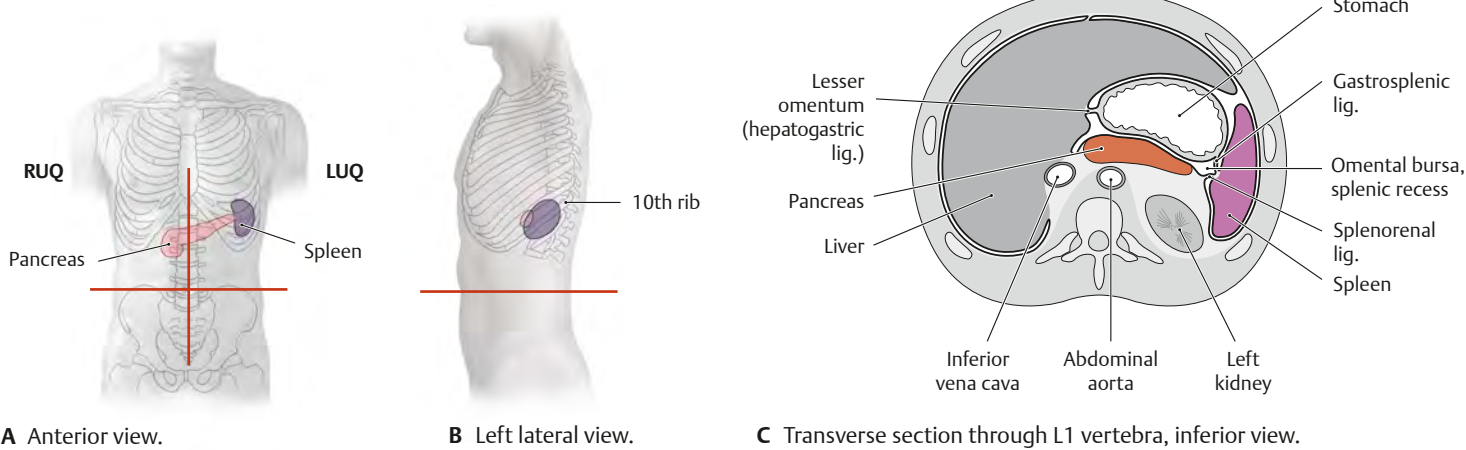


Fig. 15.31 Pancreas
Anterior view with dissection of the pancreatic duct.

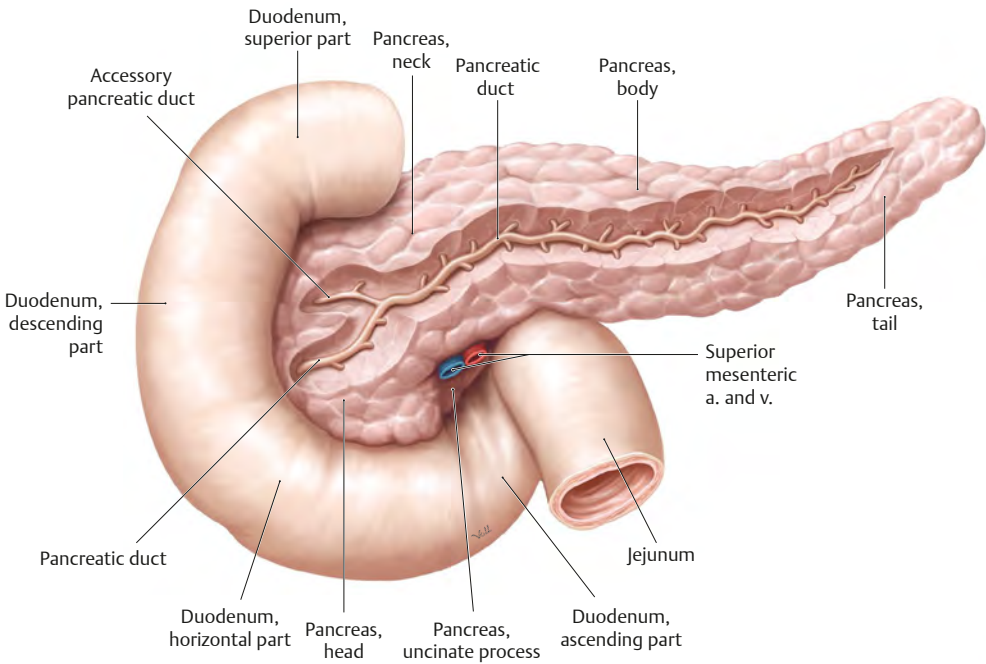


Fig. 15.32 Spleen

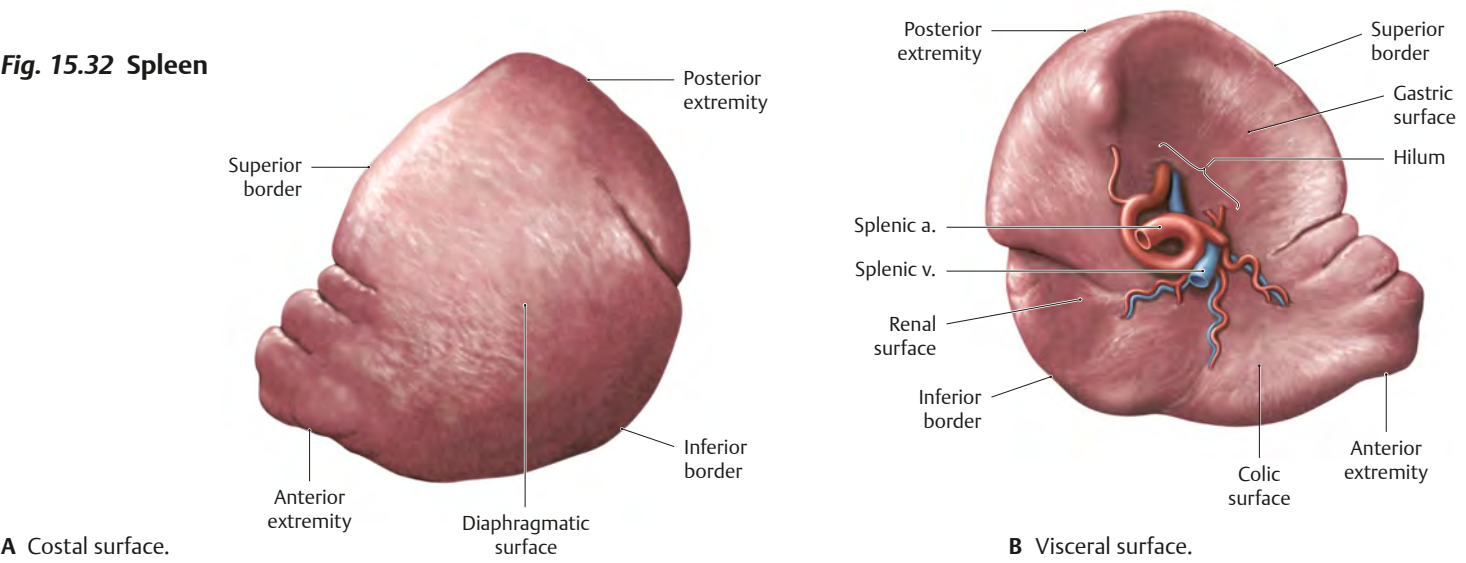
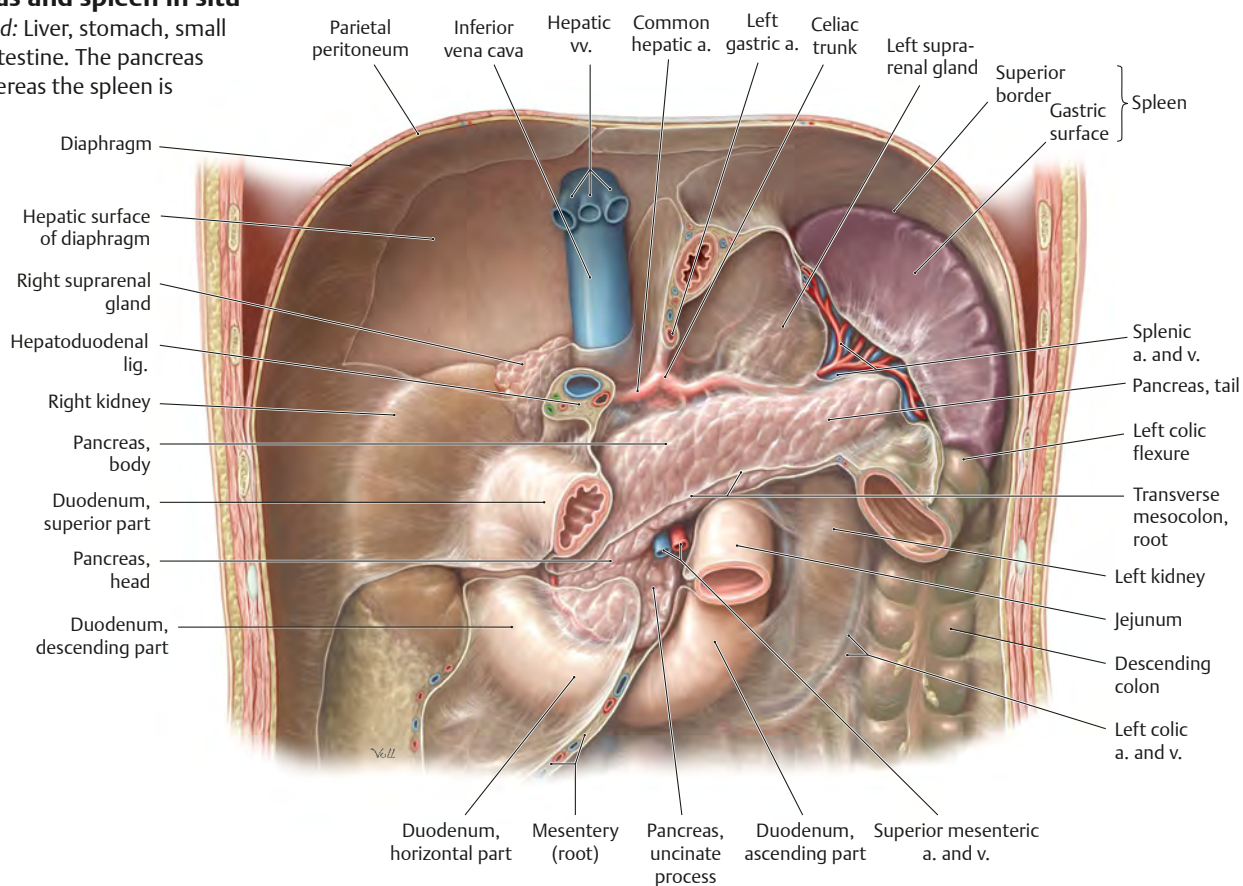
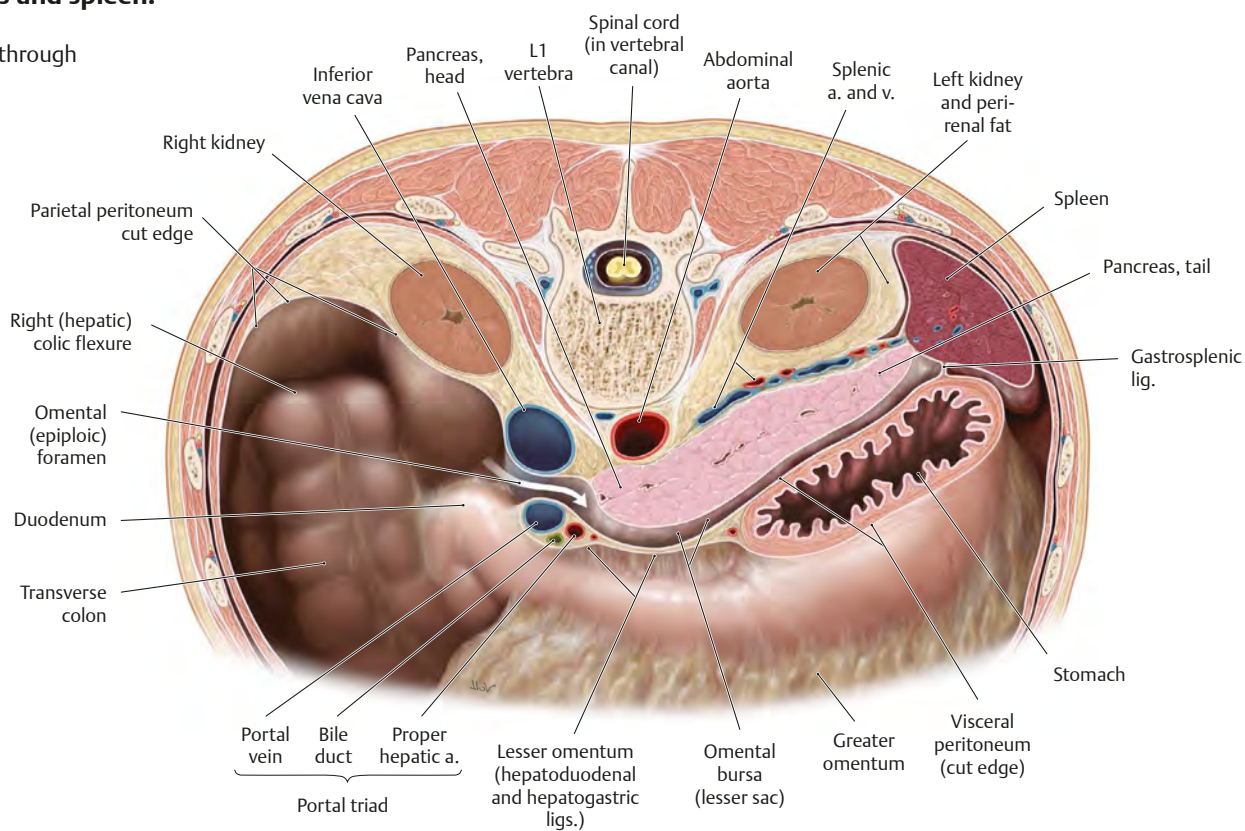
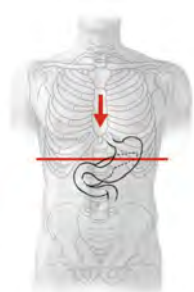


Fig. 15.33 Pancreas and spleen in situ

Anterior view. *Removed:* Liver, stomach, small intestine, and large intestine. The pancreas is retroperitoneal, whereas the spleen is intraperitoneal.

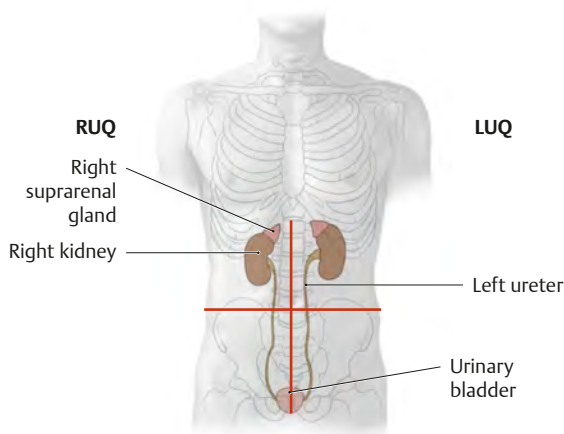
**Fig. 15.34 Pancreas and spleen: Transverse section**

Superior view. Section through L1 vertebra.

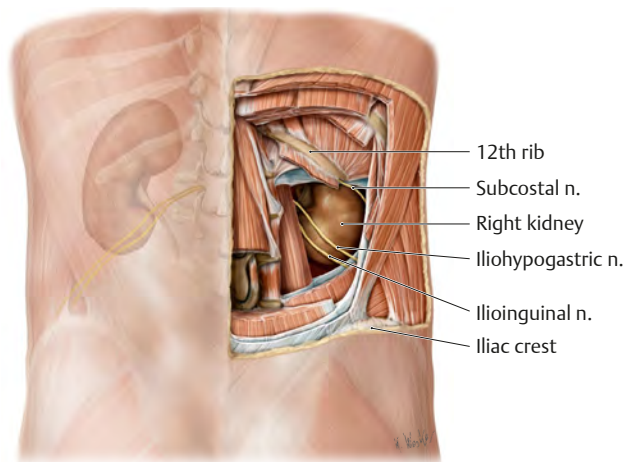


Kidneys & Suprarenal Glands (I)

Fig. 15.35 Kidneys and suprarenal glands: Location



A Anterior view.



B Posterior view. Right side windowed.

Fig. 15.36 Relations of the kidneys: areas of organ contact.
Anterior view.

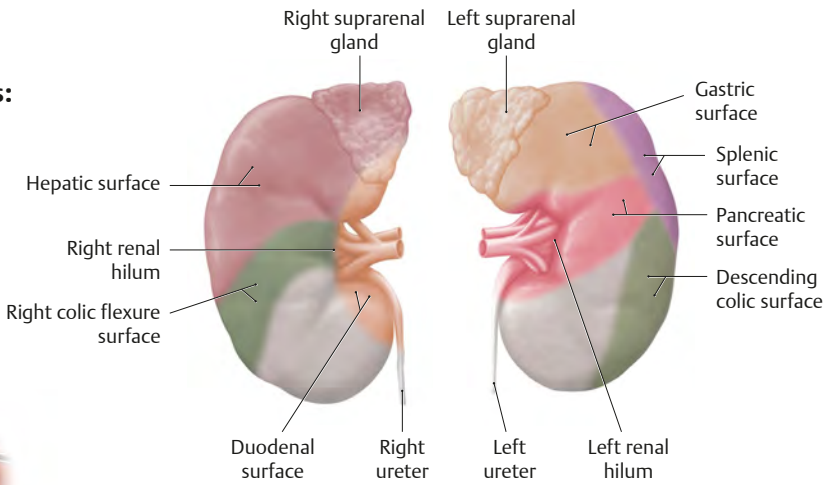
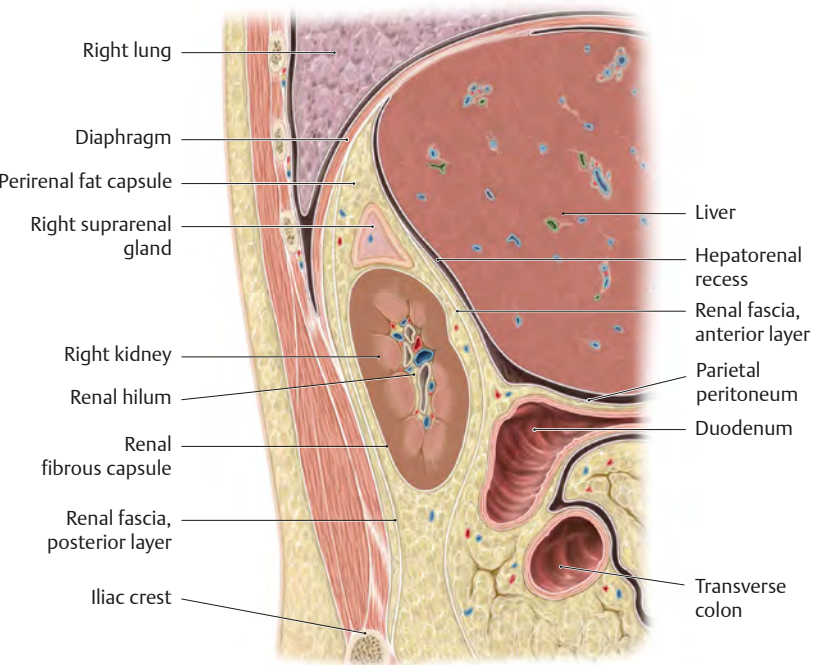
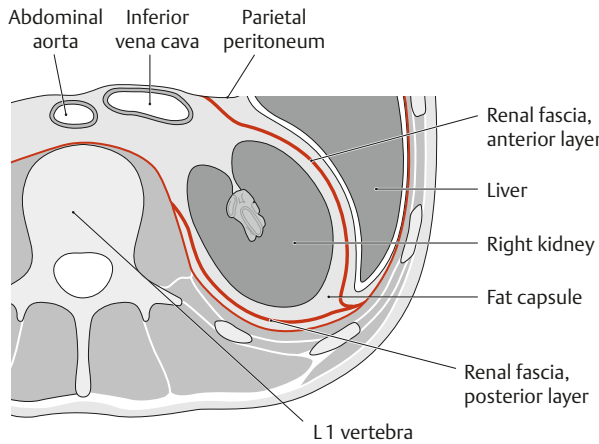


Fig. 15.37 Right kidney in the renal bed



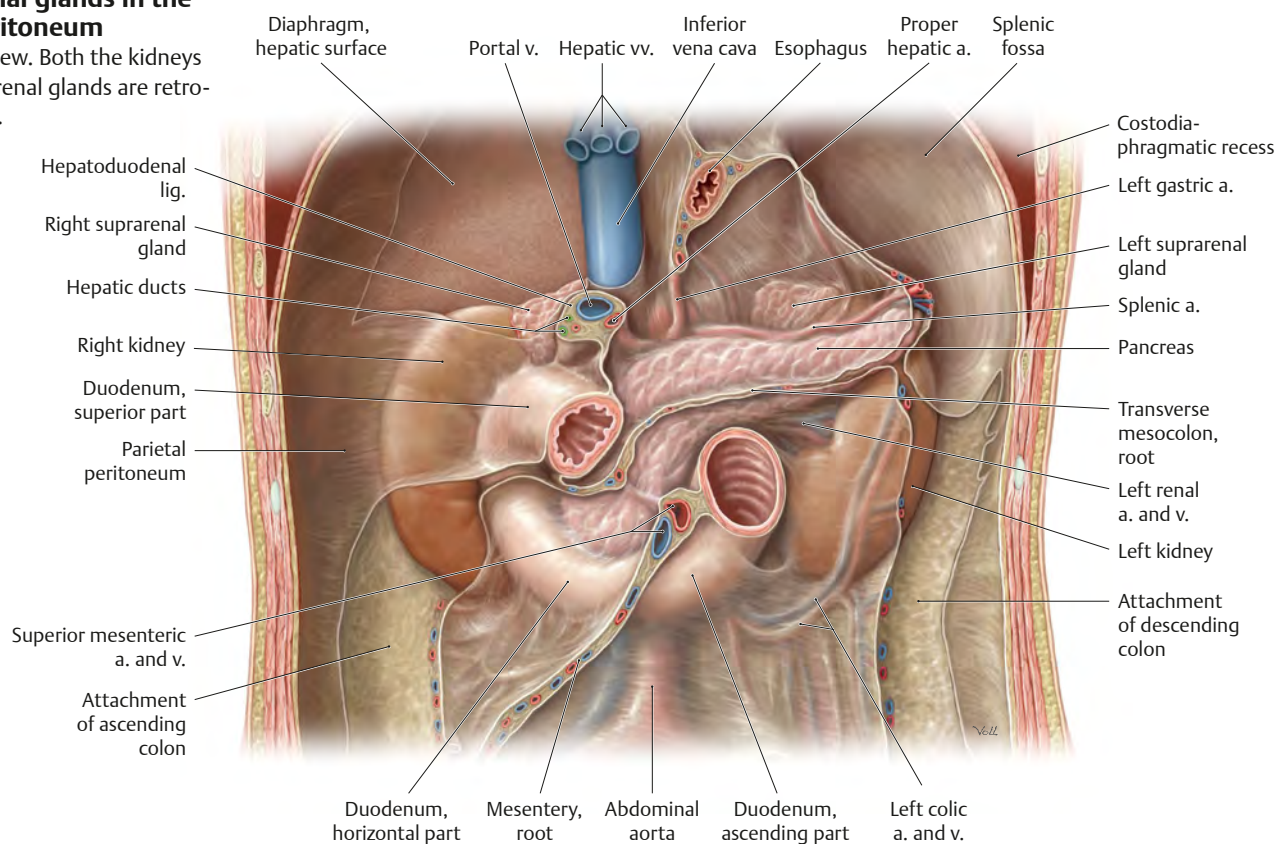
A Sagittal section at approximately the level of the renal hilum, viewed from the right side.



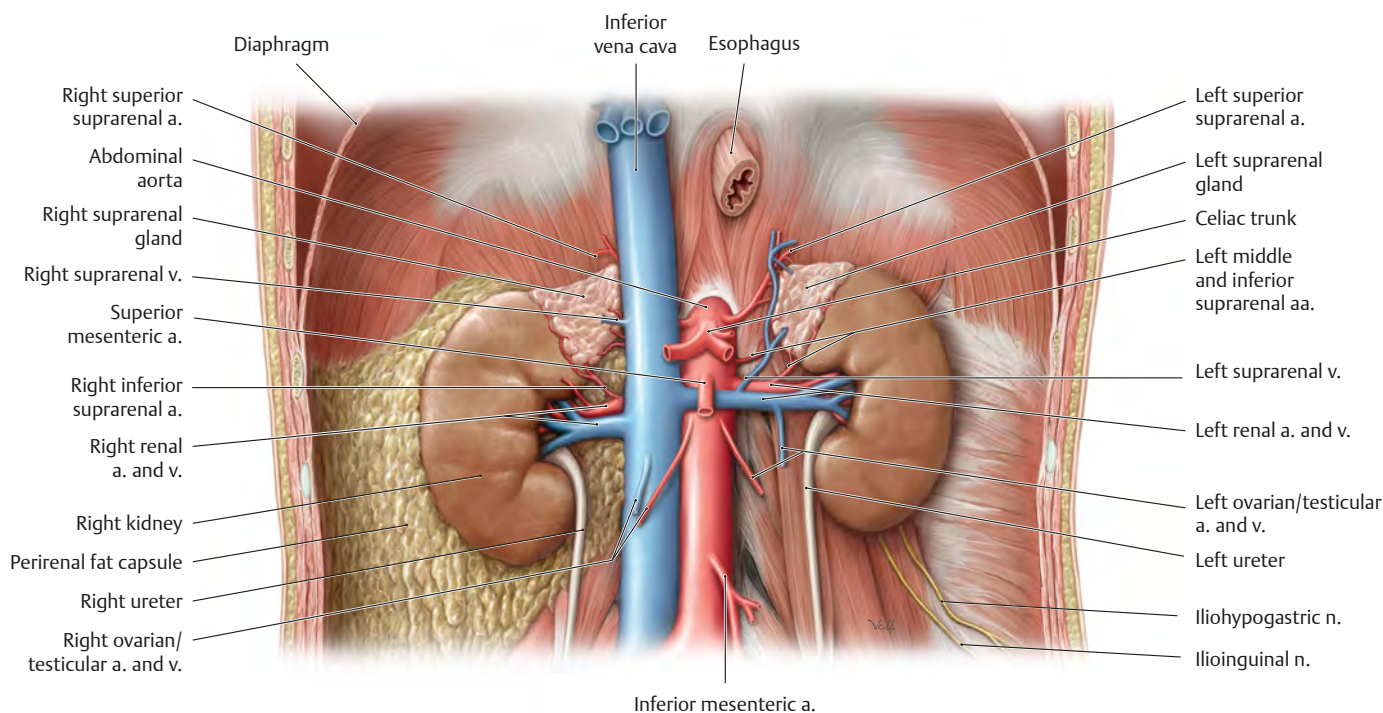
B Transverse section through the abdomen at approximately the L1/L2 level, viewed from above.

Fig. 15.38 Kidneys and suprarenal glands in the retroperitoneum

Anterior view. Both the kidneys and suprarenal glands are retroperitoneal.



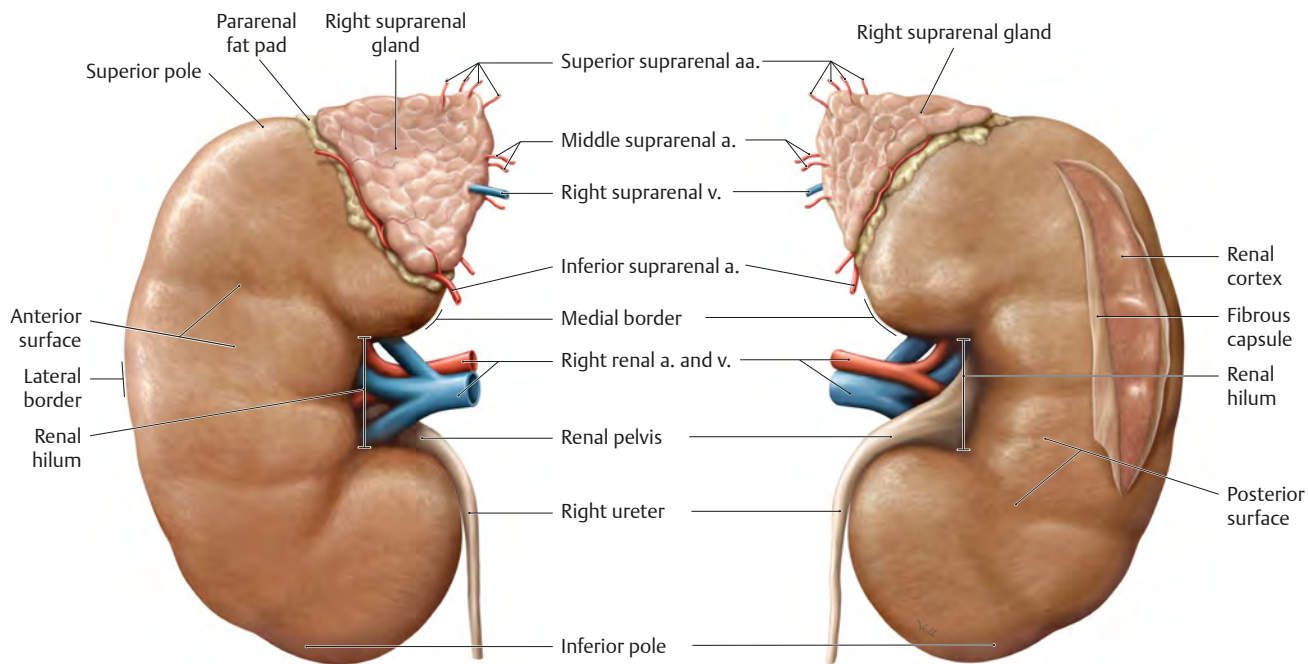
A *Removed:* Intraperitoneal organs, along with portions of the ascending and descending colon.



B *Removed:* Peritoneum, spleen and gastro-intestinal organs, along with fat capsule (left side) *Retracted:* Esophagus

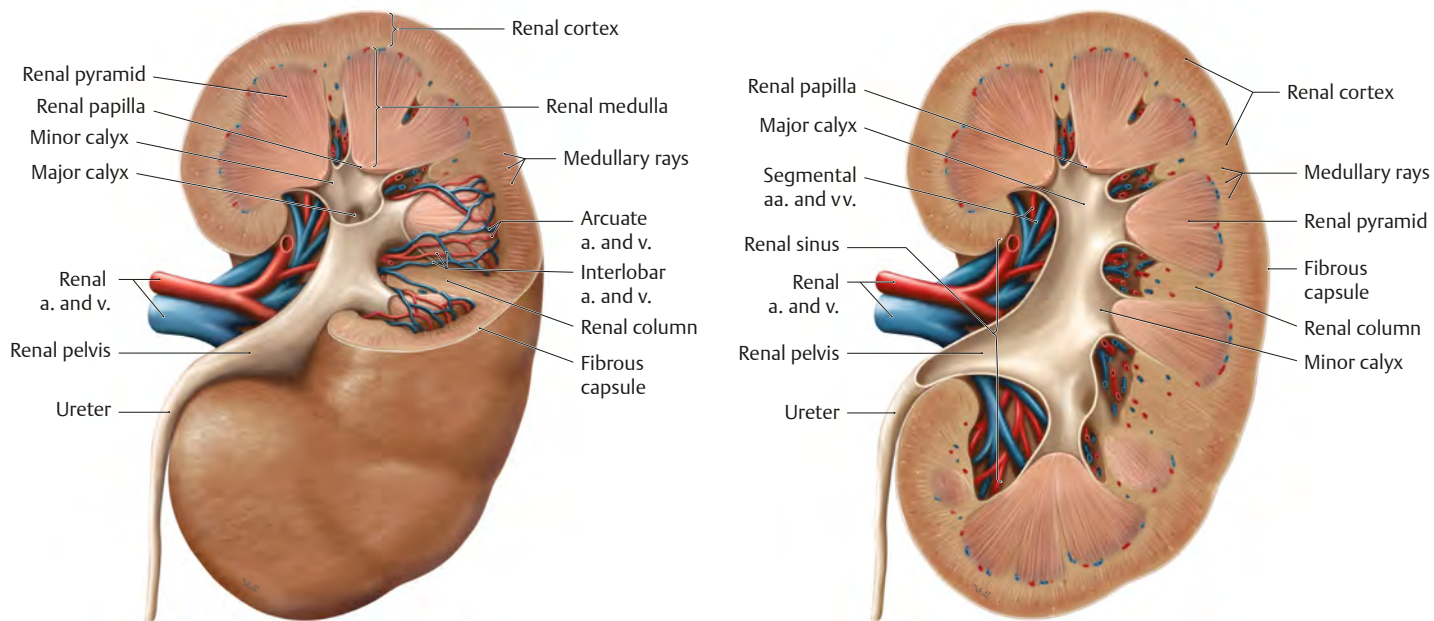
Kidneys & Suprarenal Glands (II)

Fig. 15.39 Kidney: Structure
Right kidney with suprarenal gland.



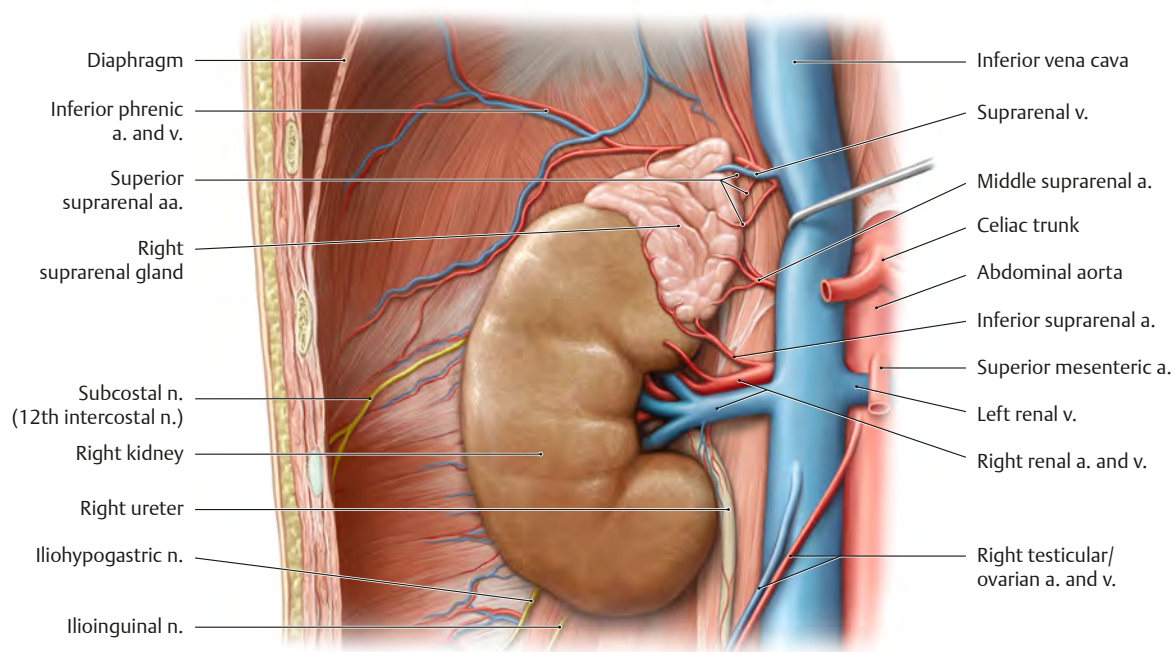
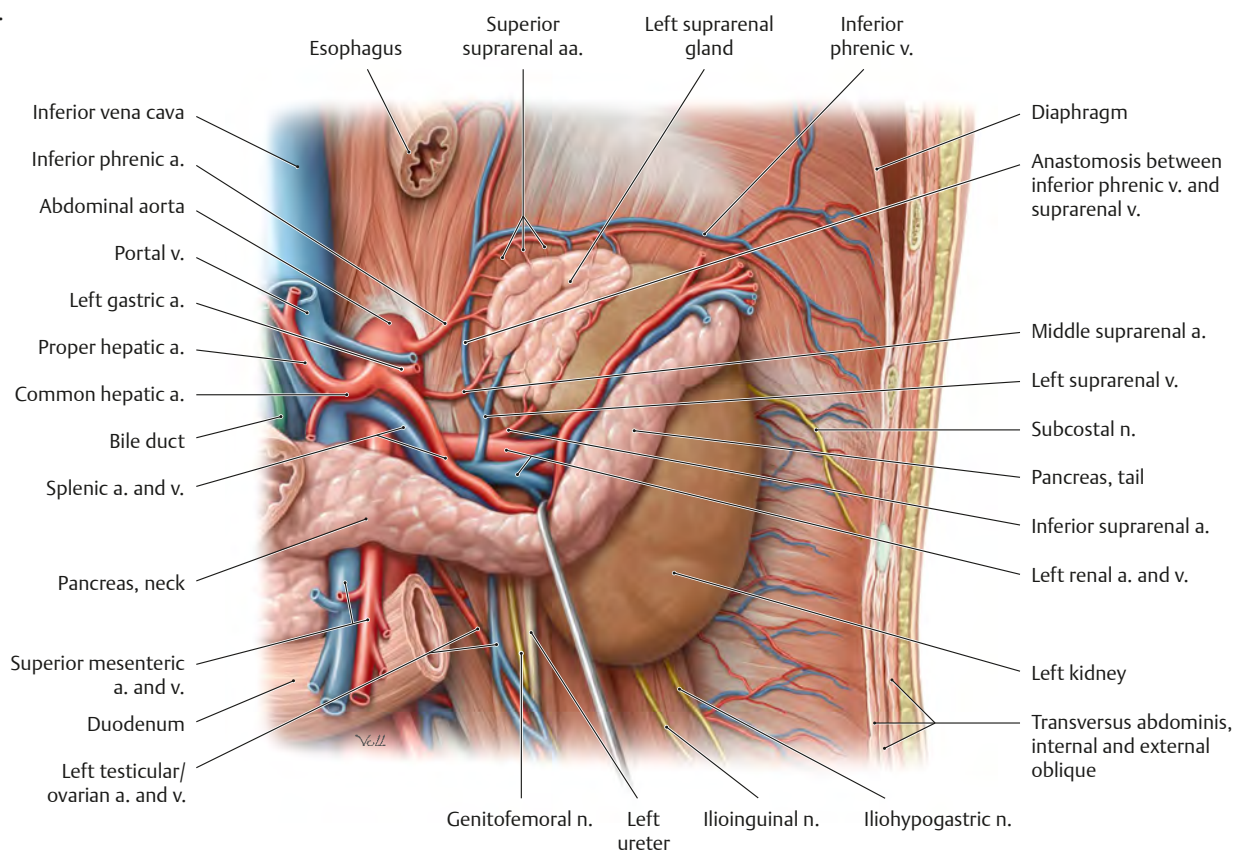
A Anterior view.

B Posterior view.



C Posterior view with upper half partially removed.

D Posterior view, midsagittal section.

Fig. 15.40 Right kidney and suprarenal glandAnterior view. *Removed:* Perirenal fat capsule.*Retracted:* Inferior vena cava.**Fig. 15.41 Left kidney and suprarenal gland**Anterior view. *Removed:* Perirenal fat capsule.*Retracted:* Pancreas.

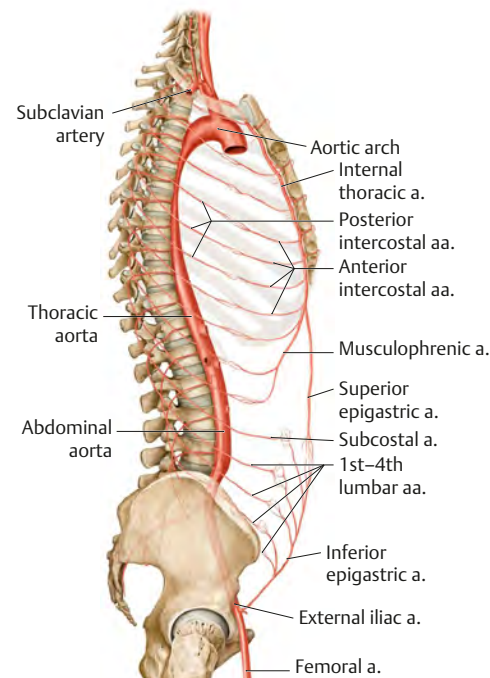
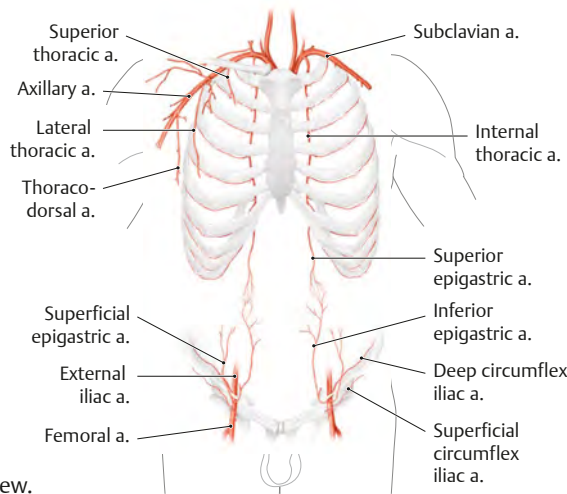
16 Neurovasculature

Arteries of the Abdominal Wall & Organs

Fig 16.1 Arteries of the abdominal wall

In addition to thoracic and abdominal aortic branches, the abdominal wall is supplied by branches of the subclavian, external iliac and femoral arteries. Numerous potential anastomoses exist between these vessels, which allows the potential for blood to bypass the abdominal aorta.

A Anterior view.



B Lateral view.

Fig. 16.2 Abdominal aorta and major branches

Anterior view. The abdominal aorta extends from T12 to its bifurcation at L4. It gives off visceral branches to the kidneys, suprarenal glands, gonads, and organs of the gastrointestinal system, and parietal branches to the body wall.

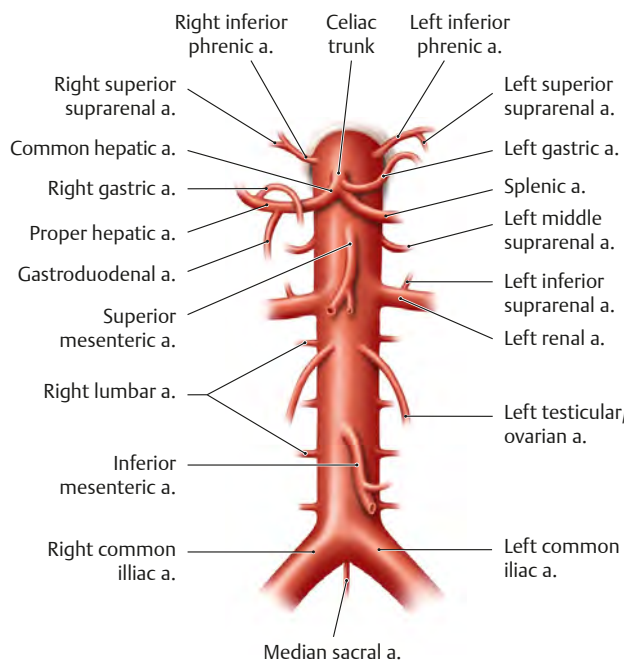
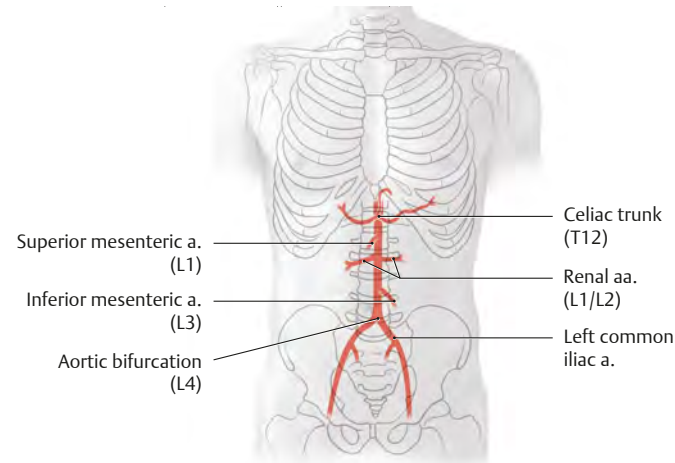
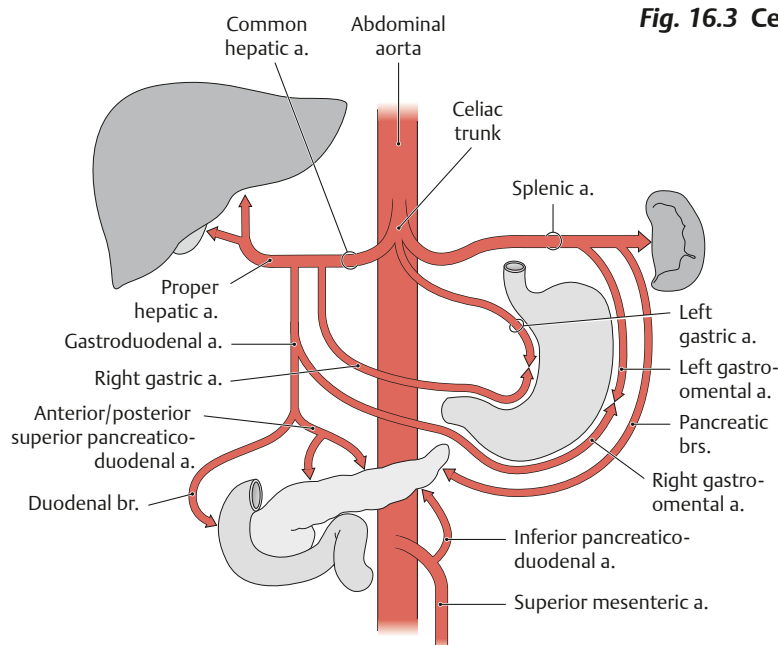
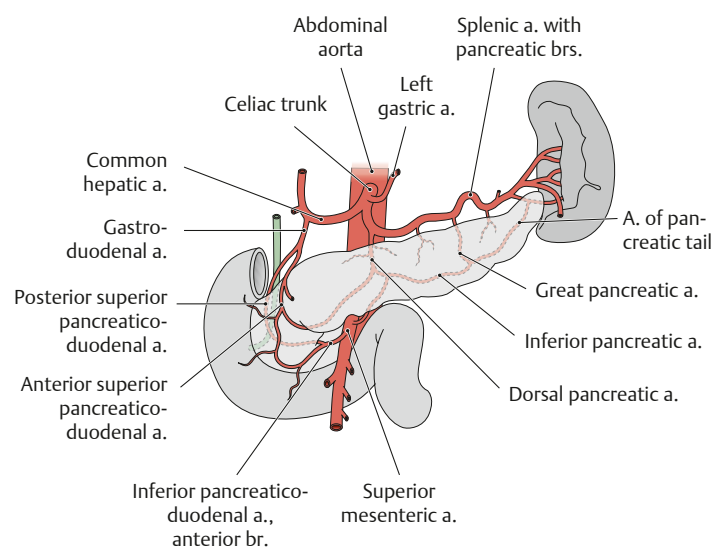
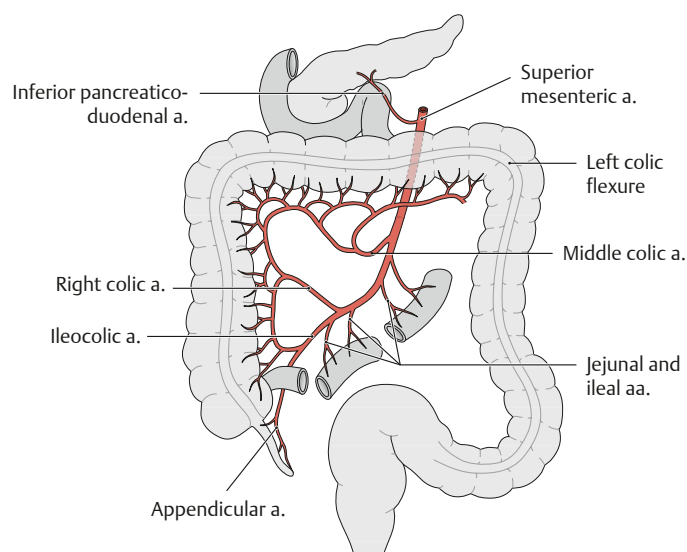
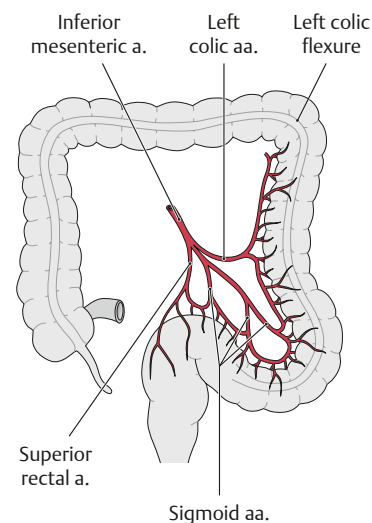


Table 16.1 Branches of the abdominal aorta

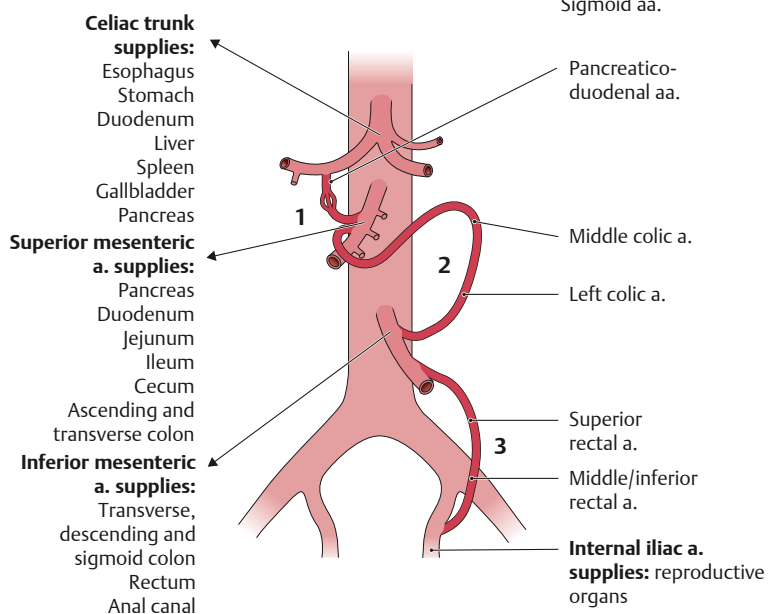
The abdominal aorta gives rise to three major unpaired trunks (bold) and the unpaired median sacral artery, as well as six paired branches.

Branch from abdominal aorta	Branches
Inferior phrenic aa. (paired)	Superior suprarenal aa.
Celiac trunk	Left gastric a.
	Splenic a.
	Common hepatic a.
	Proper hepatic a.
Middle suprarenal aa. (paired)	Right gastric a.
	Gastroduodenal a.
Superior mesenteric a.	
Renal aa. (paired)	Inferior suprarenal aa.
Lumbar aa. (1st through 4th, paired)	
Testicular/ovarian aa. (paired)	
Inferior mesenteric a.	
Common iliac aa. (paired)	External iliac a.
	Internal iliac a.
Median sacral a.	

Fig. 16.3 Celiac trunk**A** Celiac trunk distribution.**B** Arterial supply to the pancreas**Fig. 16.4 Superior mesenteric artery****Fig. 16.5 Inferior mesenteric artery****Fig. 16.6 Abdominal arterial anastomoses**

Three major anastomoses provide overlap in the arterial supply to abdominal areas to ensure adequate blood flow. Between the:

- 1—celiac trunk and the superior mesenteric artery via the pancreaticoduodenal arteries.
- 2—superior and inferior mesenteric arteries via the middle and left colic arteries.
- 3—inferior mesenteric and the internal iliac arteries via the superior and middle or inferior rectal arteries.



Abdominal Aorta & Renal Arteries

Fig. 16.7 Abdominal aorta

Anterior view of the female abdomen. *Removed:* All organs except the left kidney and suprarenal gland. The abdominal aorta is the distal continuation of the thoracic aorta (see p. 80). It enters the abdomen

at the T12 level through the aortic hiatus and courses anterior to the vertebral bodies to the left of the midline before bifurcating into the common iliac arteries at L4.

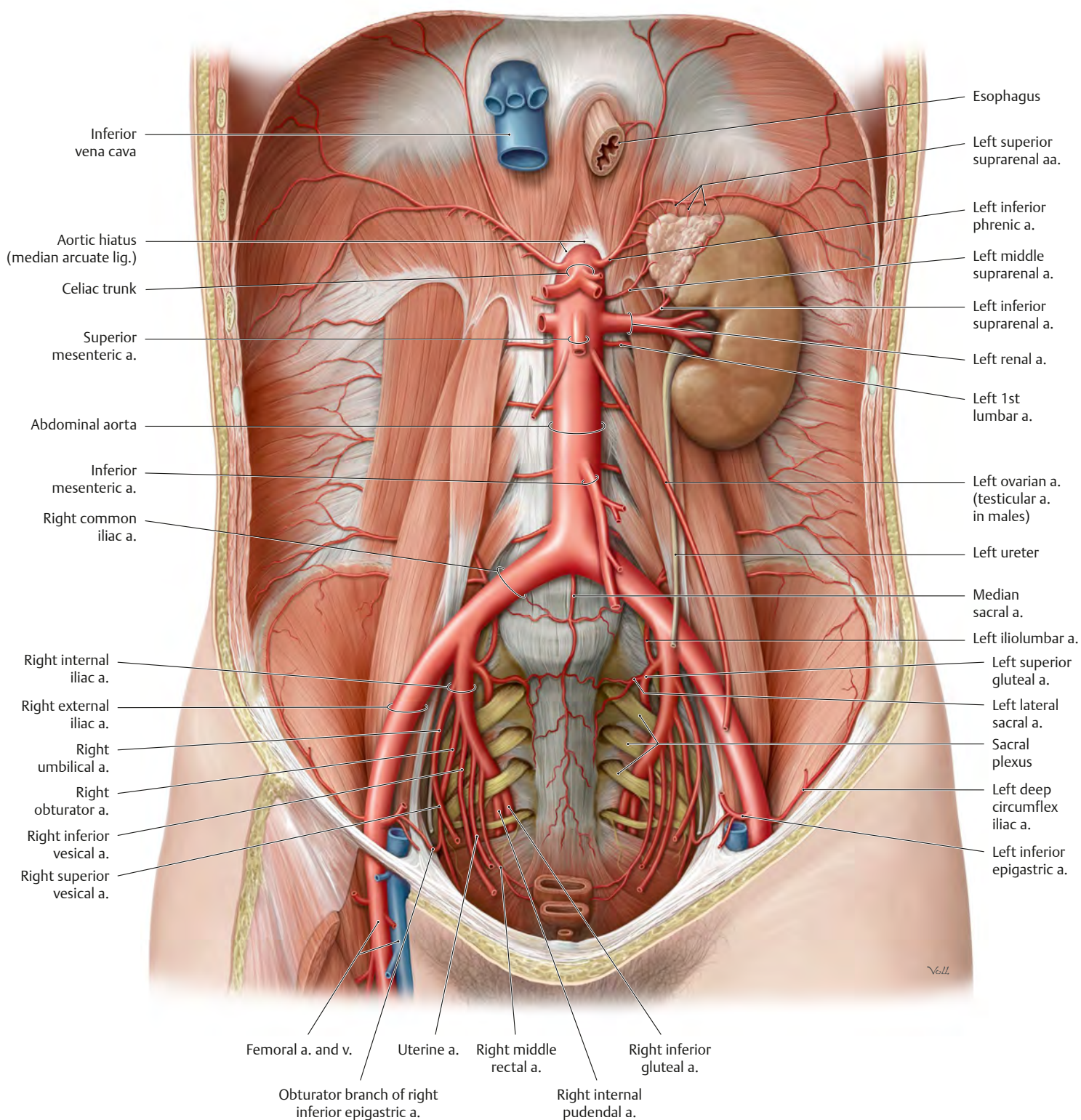
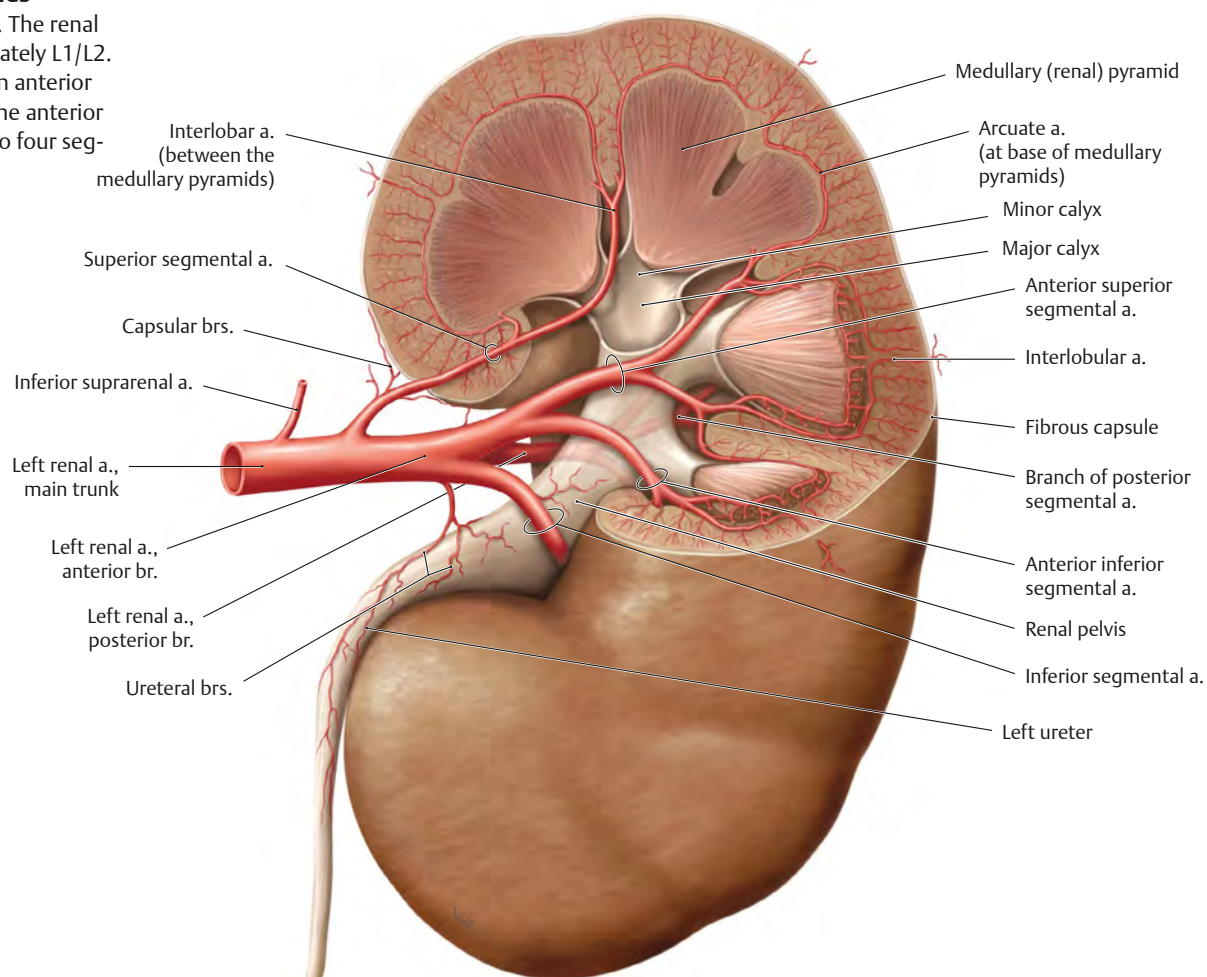
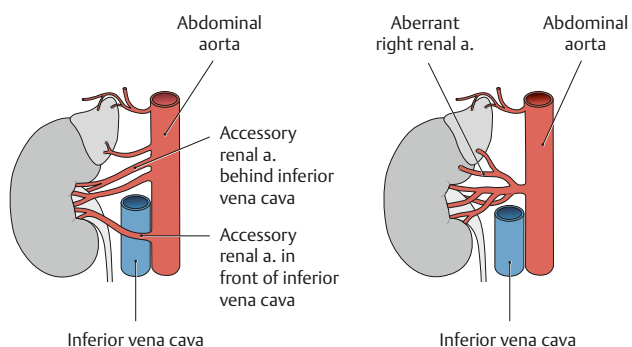


Fig. 16.8 Renal arteries

Left kidney, anterior view. The renal arteries arise at approximately L1/L2. Each artery divides into an anterior and a posterior branch. The anterior branch further divides into four segmental arteries (circled).

**Clinical box 16.1****Variants of the renal artery**

Anterior view of the right kidney. As the kidneys ascend from their site of origin in the pelvis to the lumbar region, new renal arteries are formed as older ones regress. Commonly some fail to regress, resulting in multiple arteries to one or both kidneys.



A Accessory renal arteries pass from the aorta to the renal hilum. **Note:** one of the accessory arteries is passing anterior to the inferior vena cava.

B Aberrant renal arteries do not enter the kidney at the hilum.

**Clinical box 16.2****Renal hypertension**

The kidney is an important blood pressure sensor and regulator. Stenosis (narrowing) of the renal artery reduces blood flow through the kidney and stimulates increased production of renin, an enzyme that cleaves angiotensinogen to form angiotensin I. Subsequent cleavage yields angiotensin II, which induces vasoconstriction and an increase in blood pressure. Renal hypertension should be excluded (or confirmed) when diagnosing high blood pressure.



Stenosis of the right renal artery (arrow), visible via arteriography.

Celiac Trunk

Fig. 16.9 Celiac trunk: Stomach, liver, and gallbladder
 Anterior view. *Opened:* Lesser omentum. *Incised:* Greater omentum.
 The celiac trunk arises from the abdominal aorta at about the level of T12. It supplies the structures of the foregut, the proximal part

of the alimentary canal and the spleen. The foregut consists of the esophagus (distal 1.25 cm), stomach, duodenum (proximal half), liver, gallbladder, and pancreas (superior portion).

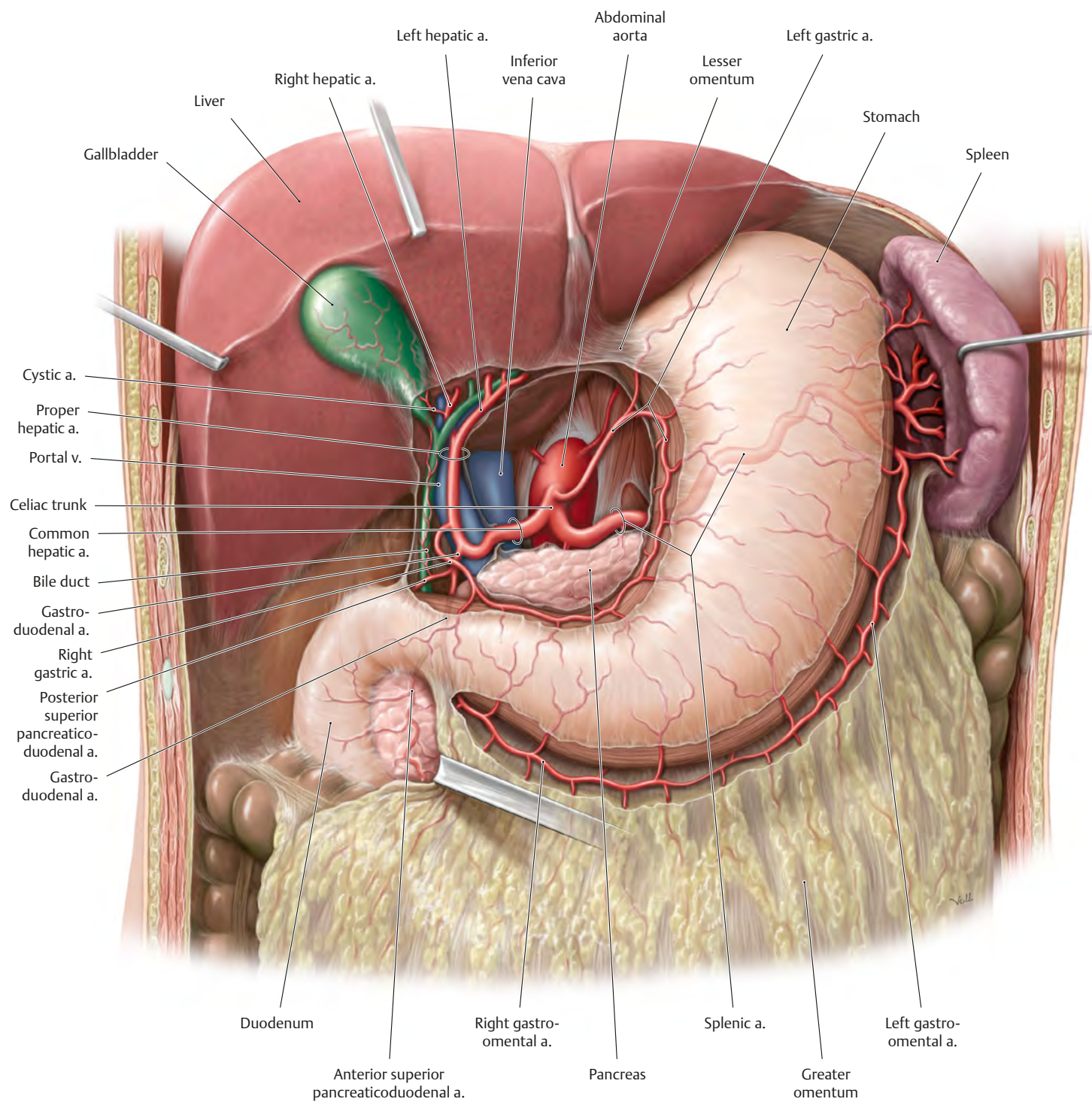
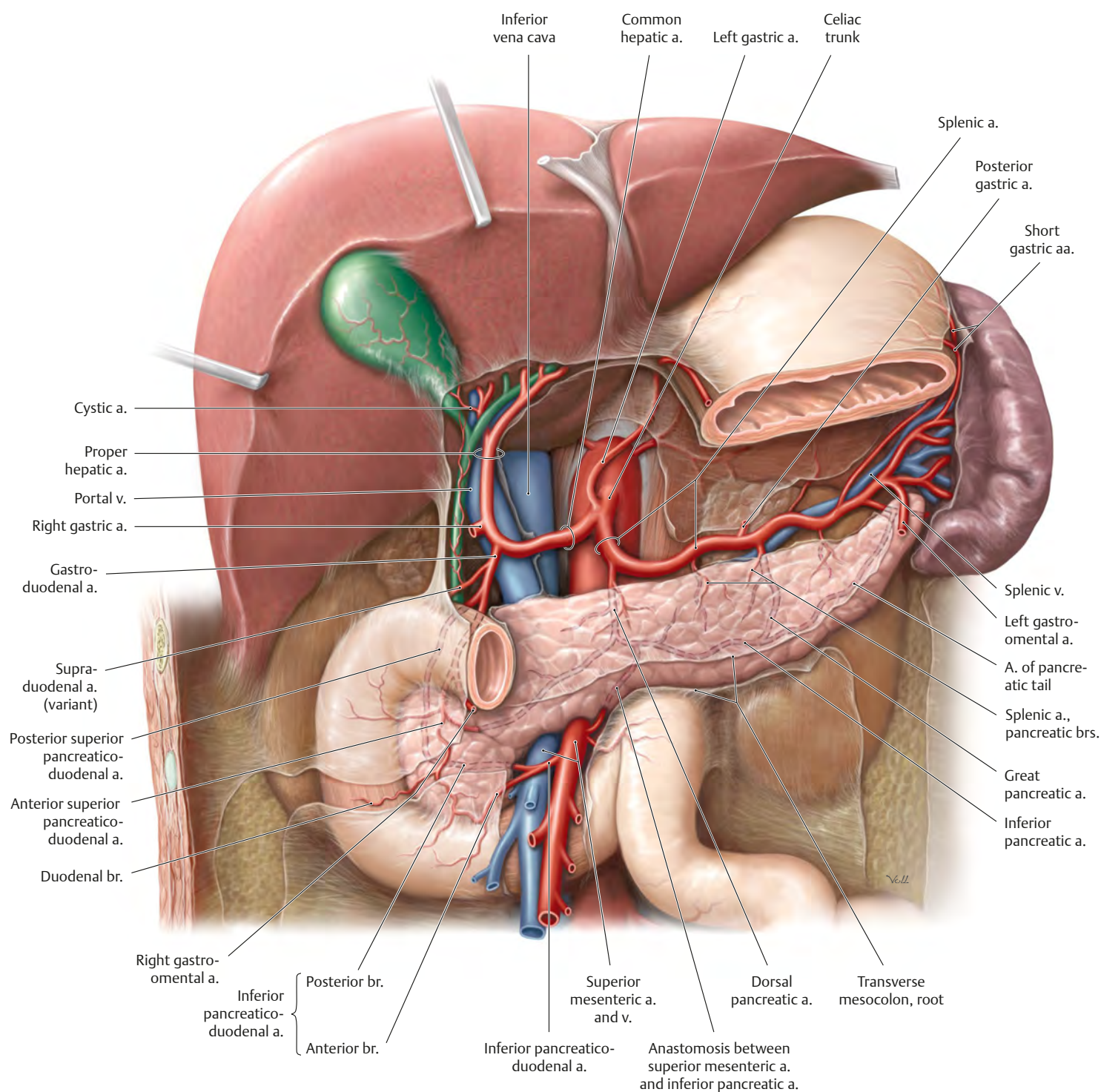


Fig. 16.10 Celiac trunk: Pancreas, duodenum, and spleen

Anterior view. *Removed:* Stomach (body) and lesser omentum.

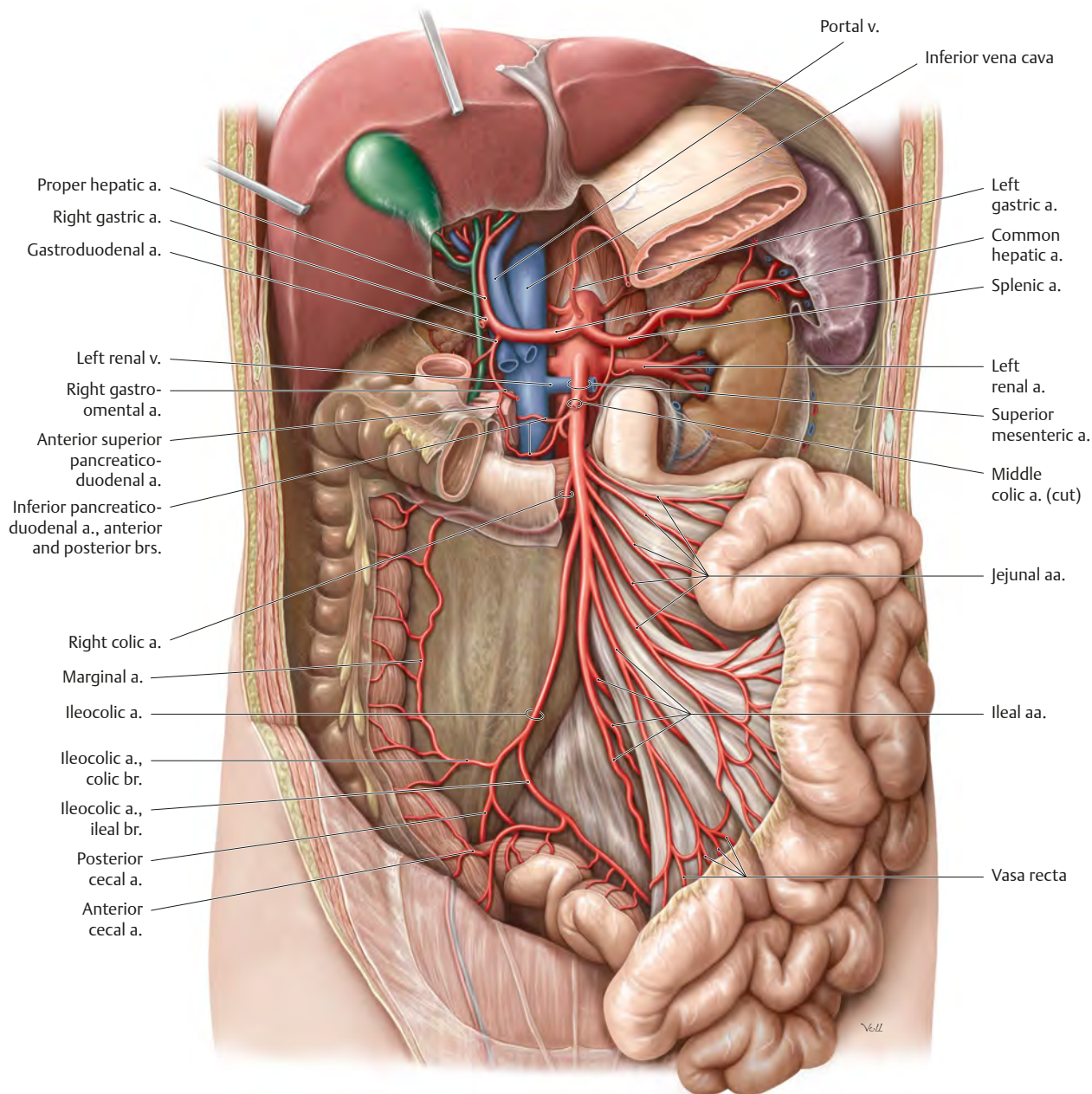


Superior & Inferior Mesenteric Arteries

Fig. 16.11 Superior mesenteric artery

Anterior view. *Partially removed:* Stomach, duodenum, and peritoneum. *Reflected:* Liver and gallbladder. *Note:* The middle colic artery has been truncated (see Fig. 16.12). The superior mesenteric artery arises from the aorta opposite L1. It supplies the structures of the midgut: the

duodenum (distal half), jejunum and ileum, cecum and appendix, ascending colon, right colic flexure, and the proximal two thirds of the transverse colon.



Clinical box 16.3

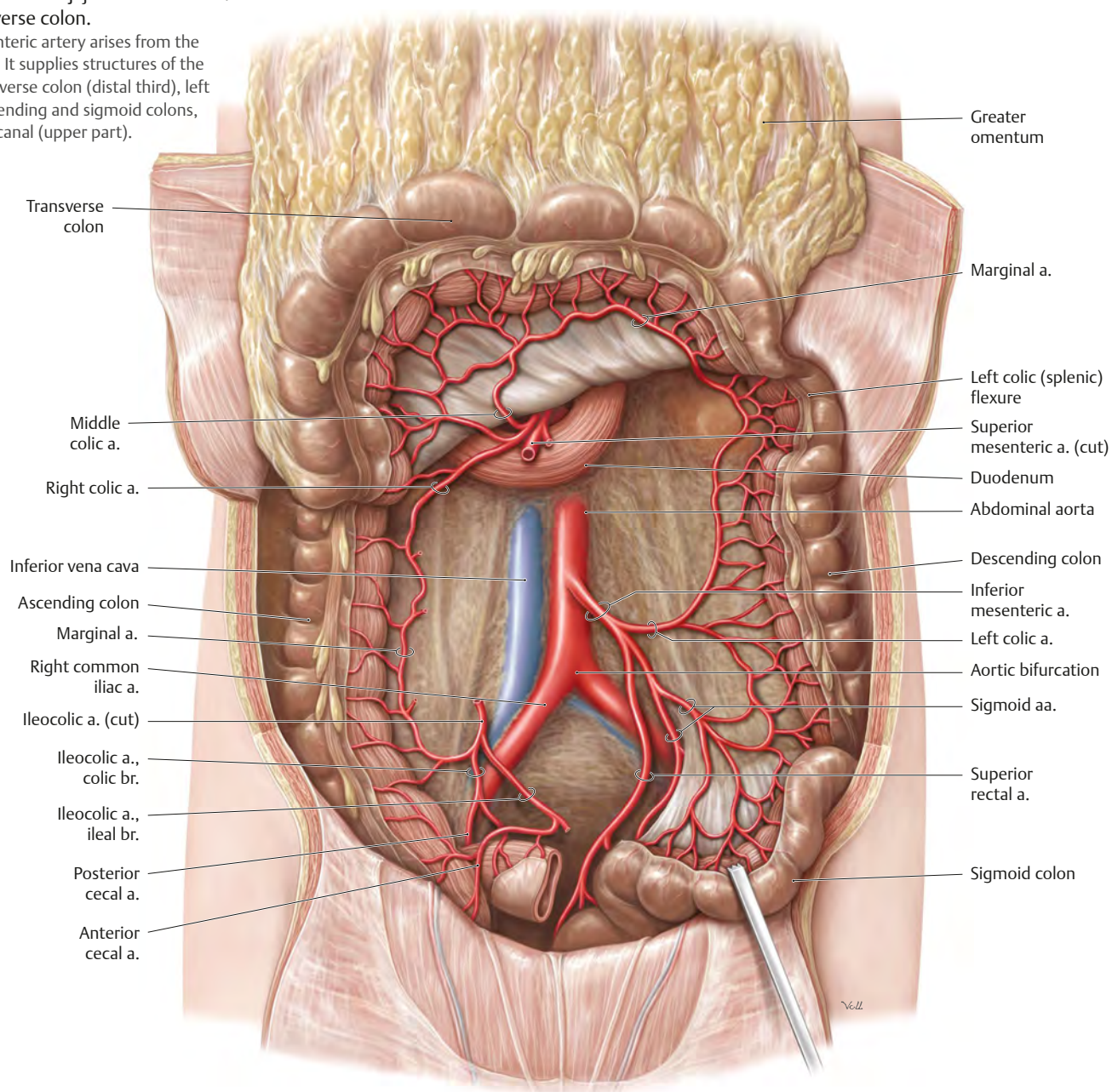
Mesenteric ischemia

A decrease in blood flow to the intestine (ischemia) can result from occlusion of the superior mesenteric artery (SMA) by a thrombus or embolus (acute) or may be secondary to severe atherosclerosis (chronic). In the acute condition, the embolus can obstruct the SMA at its origin or, if small enough, may travel further to obstruct a more peripheral branch. Acute ischemia results in necrosis of the affected part of the intestine. Chronic ischemia is less

threatening since obstruction of the vessels occurs gradually, allowing the formation of collateral vessels that will supply the affected intestine. Because of the extensive anastomoses between intestinal arteries, chronic vascular ischemia is rare. Symptoms occur only if two of the three major vessels (celiac trunk or superior or inferior mesenteric arteries) are compromised.

Fig. 16.12 Inferior mesenteric arteryAnterior view. *Removed:* Jejunum and ileum.*Reflected:* Transverse colon.

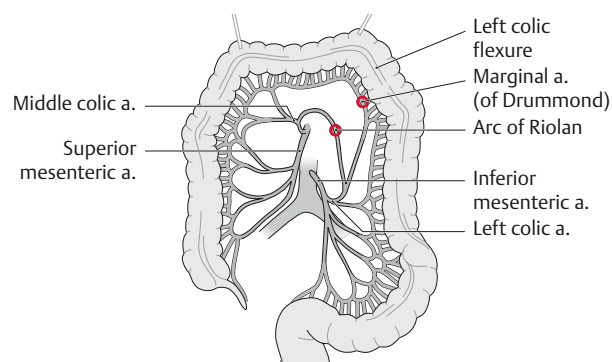
The inferior mesenteric artery arises from the aorta opposite L3. It supplies structures of the hindgut: the transverse colon (distal third), left colic flexure, descending and sigmoid colons, rectum, and anal canal (upper part).

**Clinical box 16.4****Anastomoses between arteries of the large intestine**

Anastomoses between branches of the superior mesenteric and inferior mesenteric arteries can compensate for abnormally low blood flow in either of the arteries. Two of these anastomoses, although variable, are of significant value:

Riolan's arcade (arc of Riolan) – a connection between the middle colic artery and the left colic artery that arises close to their origins from the superior and inferior mesenteric arteries, respectively.

Marginal artery (of Drummond) – a connection between all arteries of the colon that runs along the periphery of the mesentery close to the intestinal tube.



Veins of the Abdominal Wall & Organs

Fig 16.13 Veins of the abdominal wall

The abdominal wall is drained by veins that accompany the arteries and are tributaries of the azygos system and inferior vena cava. Additionally, a large thoracoepigastric vein connects the femoral and axillary veins.

A Anterior view.

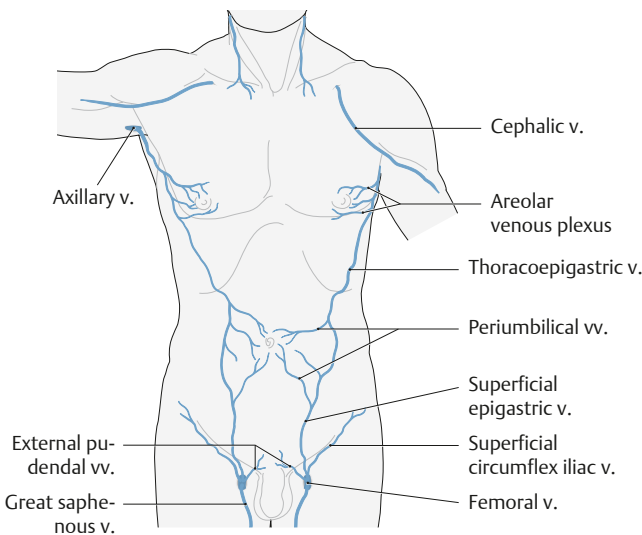
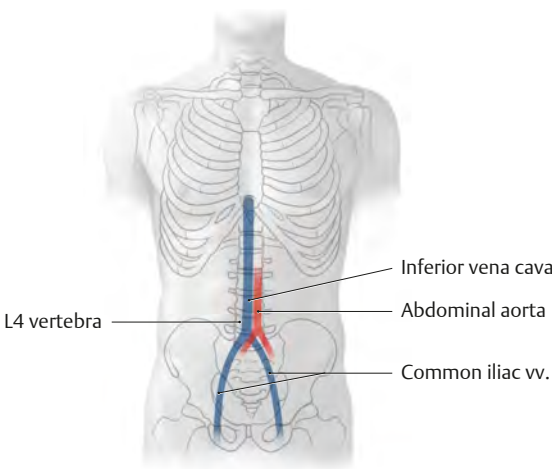


Fig. 16.14 Inferior vena cava

Anterior view. The inferior vena cava arises at L5 with the convergence of the common iliac veins. It ascends along the right side of the vertebral column, passes through the caval opening in the diaphragm at T8 and terminates in the thorax in the right atrium of the heart.



B Lateral view.

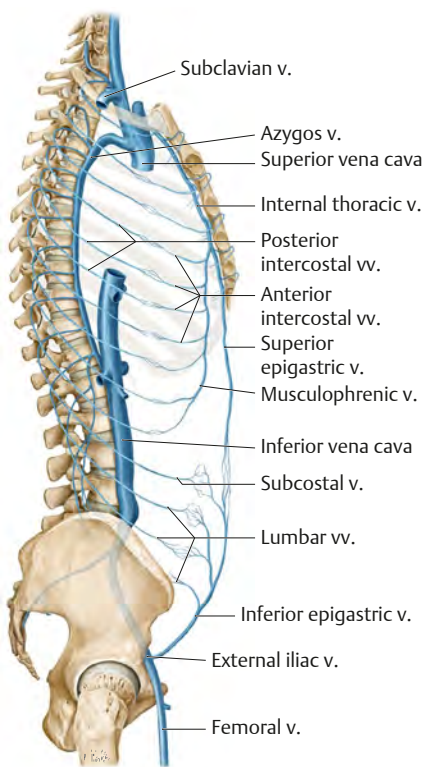


Table 16.2		Tributaries of the inferior vena cava
①R	①L	Inferior phrenic vv. (paired)
②		Hepatic vv. (3)
③R	③L	Suprarenal vv. (the right vein is a direct tributary)
④R	④L	Renal vv. (paired)
⑤R	⑤L	Testicular/ovarian vv. (the right vein is a direct tributary)
⑥R	⑥L	Ascending lumbar vv. (paired), not direct tributaries
⑦R	⑦L	Lumbar vv.
⑧R	⑧L	Common iliac vv. (paired)
⑨		Median sacral v.

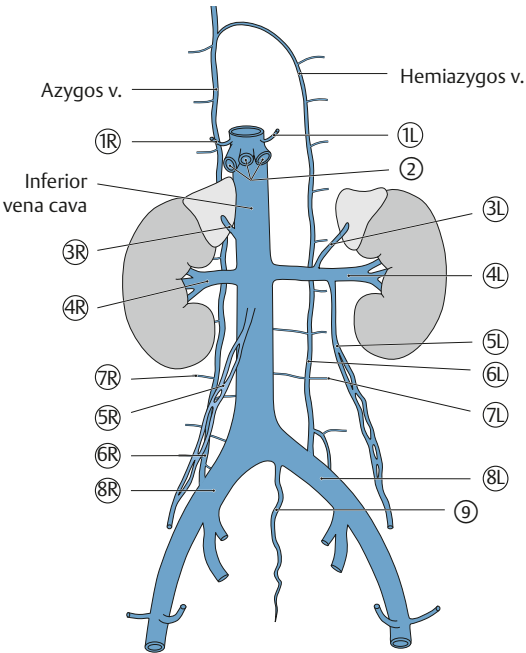
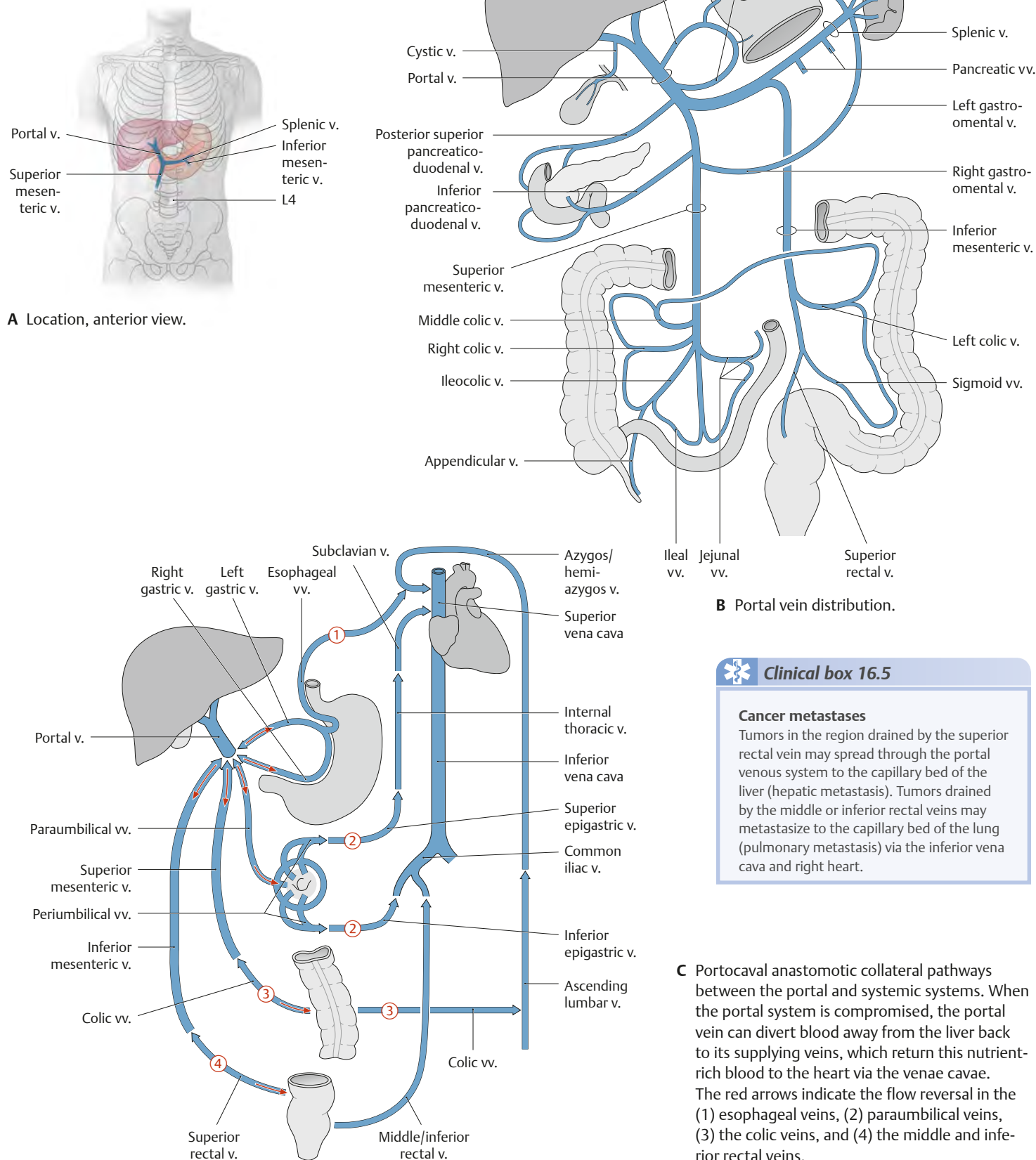


Fig. 16.15 Portal vein

The portal vein (see **p. 198**) drains venous blood from the abdominopelvic organs supplied by the celiac trunk and superior and inferior mesenteric arteries.



C Portocaval anastomotic collateral pathways between the portal and systemic systems. When the portal system is compromised, the portal vein can divert blood away from the liver back to its supplying veins, which return this nutrient-rich blood to the heart via the venae cavae. The red arrows indicate the flow reversal in the (1) esophageal veins, (2) paraumbilical veins, (3) the colic veins, and (4) the middle and inferior rectal veins.

Inferior Vena Cava & Renal Veins

Fig. 16.16 Inferior vena cava

Anterior view of the female abdomen. *Removed:* All organs except the left kidney and suprarenal gland. The inferior vena cava courses along the right side of the vertebral bodies from its origin at L5 to the caval opening in the diaphragm at T8. Unlike the branches of the aorta, vis-

ceral and parietal drainages to the inferior vena cava are asymmetrical (note drainages of the suprarenal glands, gonads and azygos veins). It communicates with the azygos system through lumbar veins and receives blood from the portal venous system via the hepatic veins.

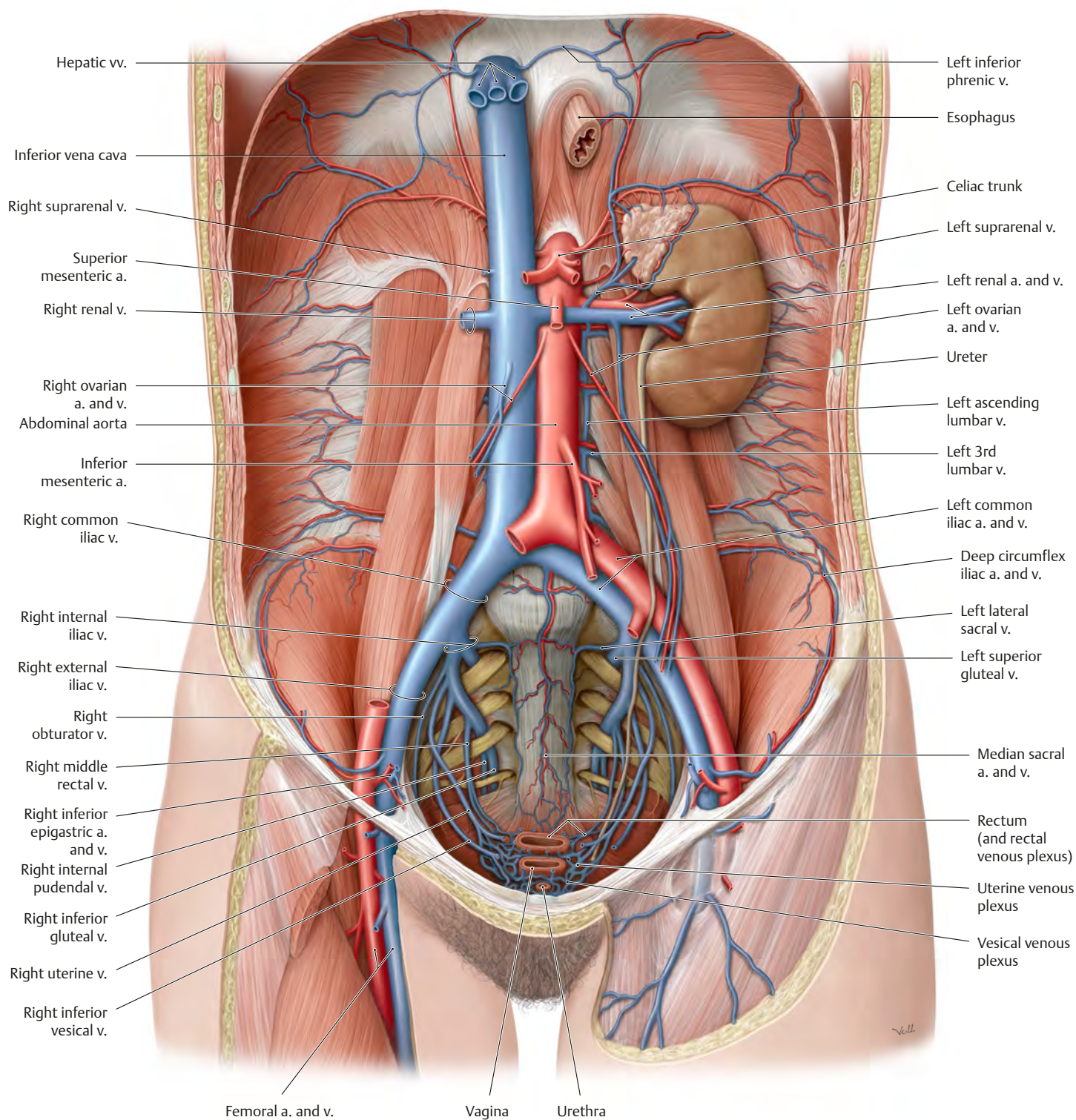
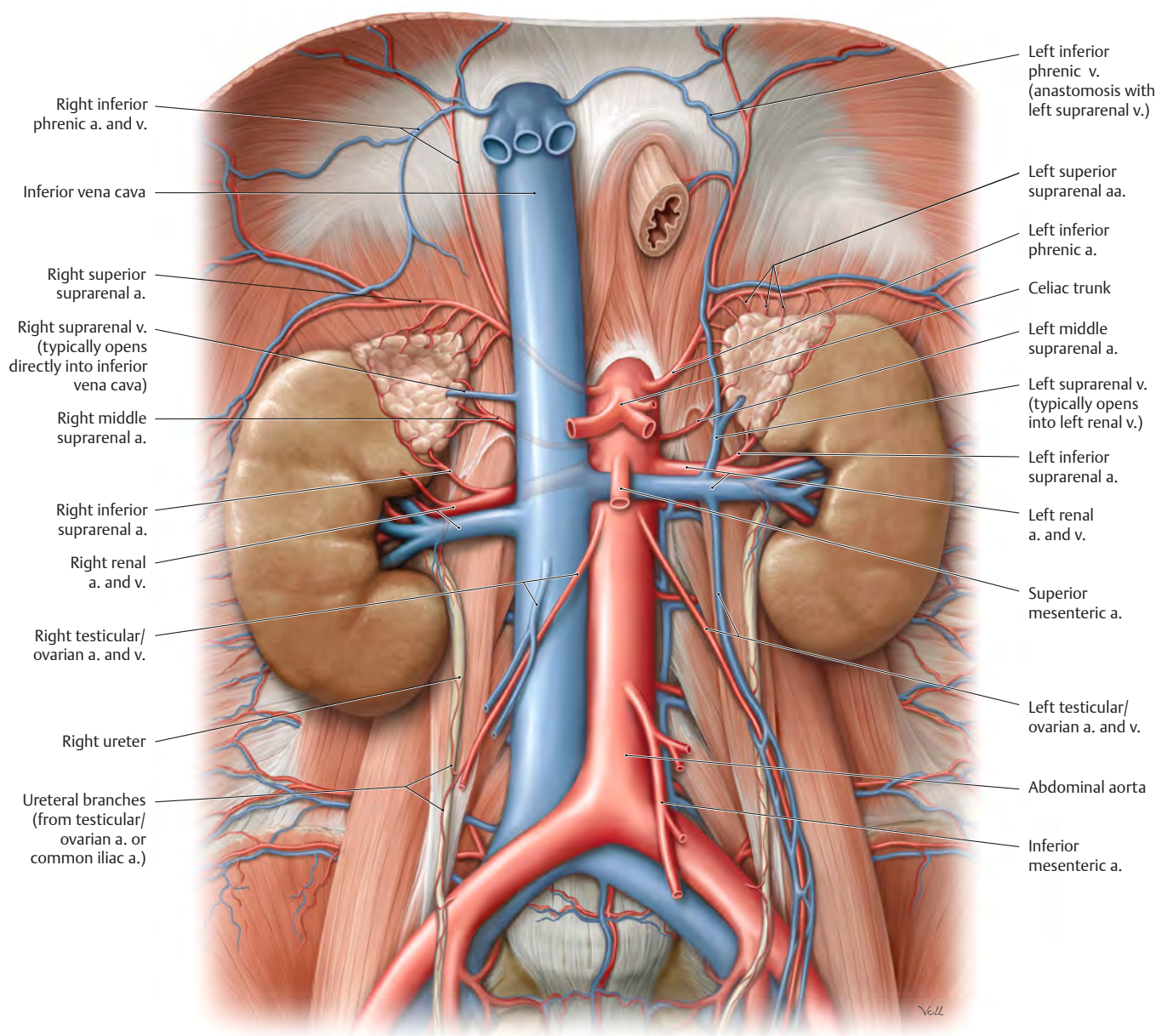


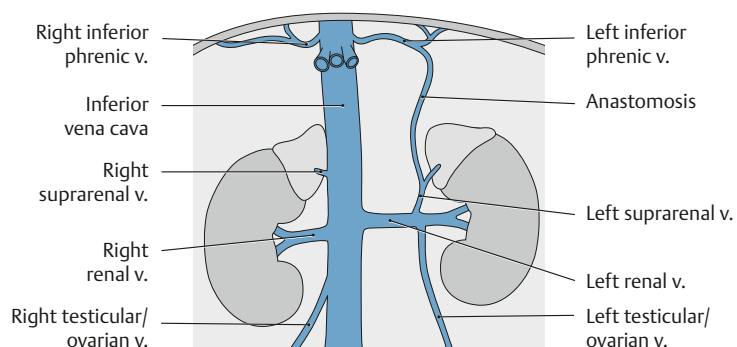
Fig. 16.17 Renal veins

Anterior view. See **p. 189** for the renal arteries in isolation.

Removed: All organs except kidneys and suprarenal glands.

**Clinical box 16.6****Tributaries of the left renal vein**

On the right side, the suprarenal and testicular/ovarian veins drain directly into the inferior vena cava. The corresponding veins on the left side, however, drain into the left renal vein. (This is a remnant from early development when there were both right and left sided venae cavae.) It is believed that this asymmetrical drainage pattern is the cause of the varicose dilations of the veins in the spermatic cord (varicoceles) that occur more commonly on the left side.

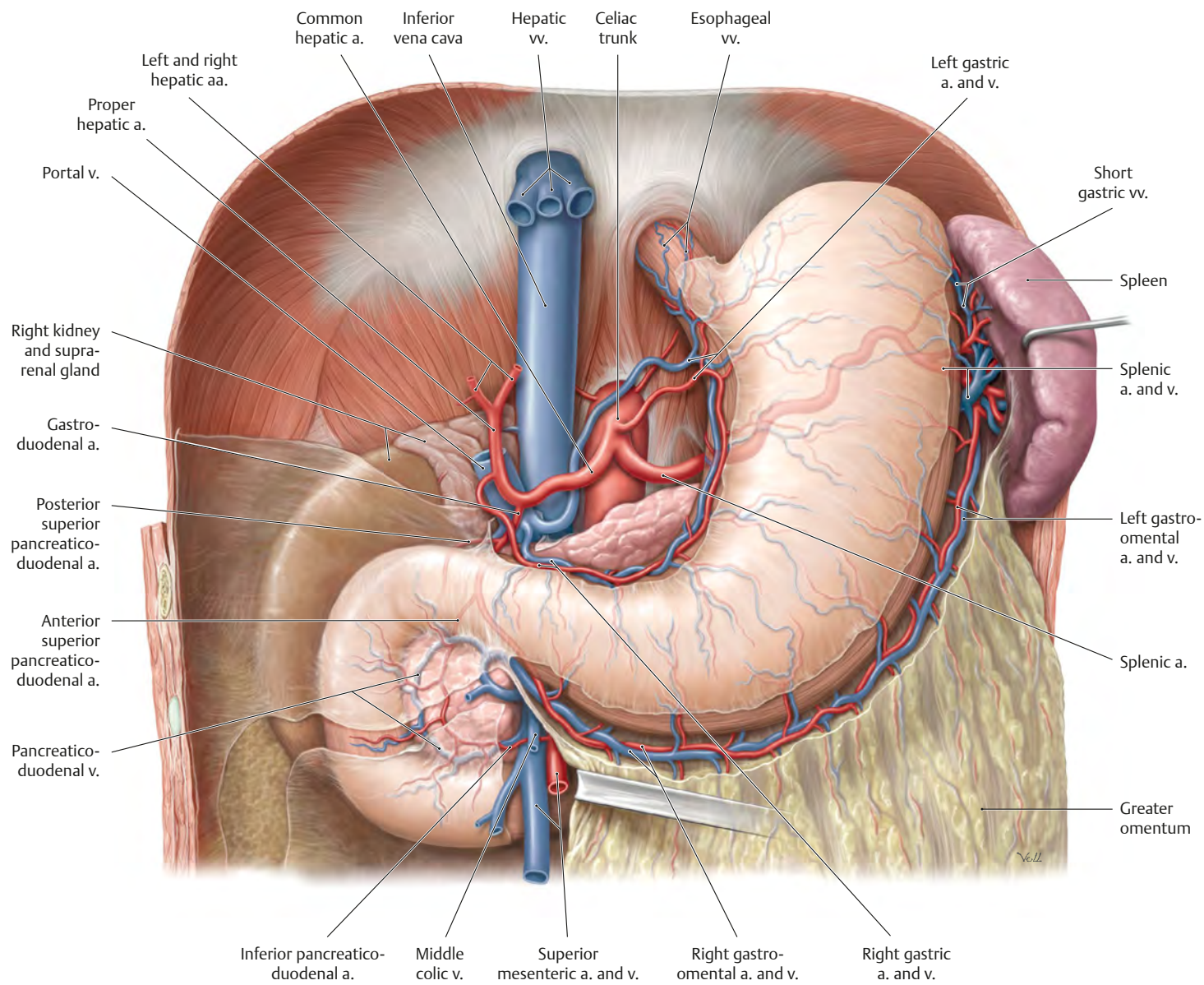


Portal Vein

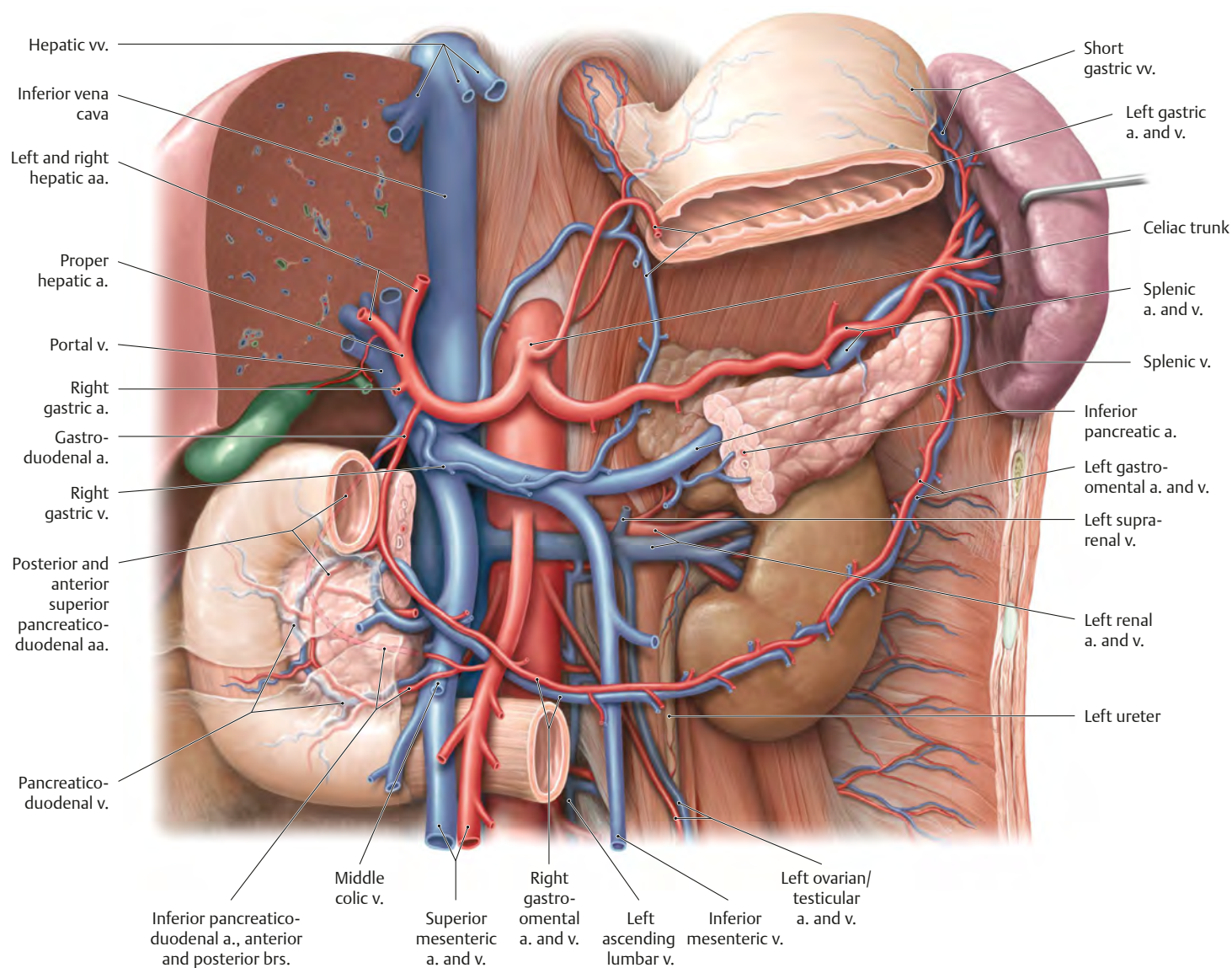
Fig. 16.18 Portal vein: Stomach and duodenum

Anterior view. *Removed:* Liver, lesser omentum, and peritoneum.
Opened: Greater omentum. The portal vein is typically formed by the

union of the superior mesenteric and the splenic veins posterior to the neck of the pancreas.



Anterior view. *Partially removed*: Liver, stomach, pancreas, and peritoneum.



Clinical box 16.7

Upper esophageal veins drain into the azygos system, but the lower esophagus drains into the portal system via the left gastric veins. As a result of this portocaval anastomosis, venous varices (dilations, *arrows*) of the esophageal wall may develop in patients with portal hypertension. Severe acute hemorrhage is the greatest risk associated with this condition.



Superior & Inferior Mesenteric Veins

Fig. 16.20 Superior mesenteric vein

Anterior view. *Partially removed:* Stomach, duodenum, and peritoneum. *Removed:* Pancreas, greater omentum, and transverse colon. *Reflected:* Liver and gallbladder. *Displaced:* Small intestine. The superior mesenteric vein receives tributaries from the entire small intestine as well as

the cecum, appendix, ascending colon, and two thirds of the transverse colon. It normally lies to the right of the superior mesenteric artery then joins with the splenic vein posterior to the neck of the pancreas to form the portal vein.

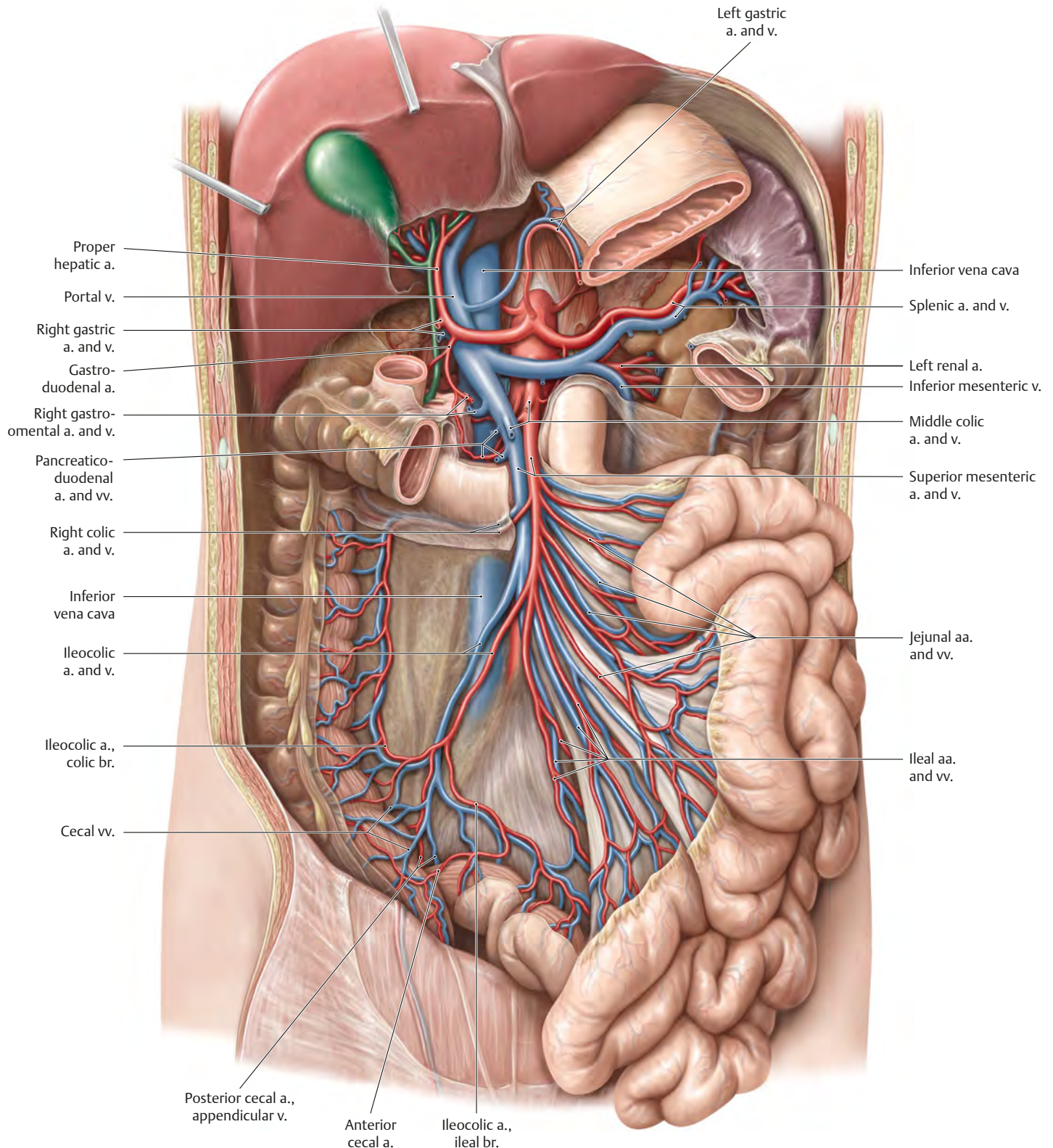
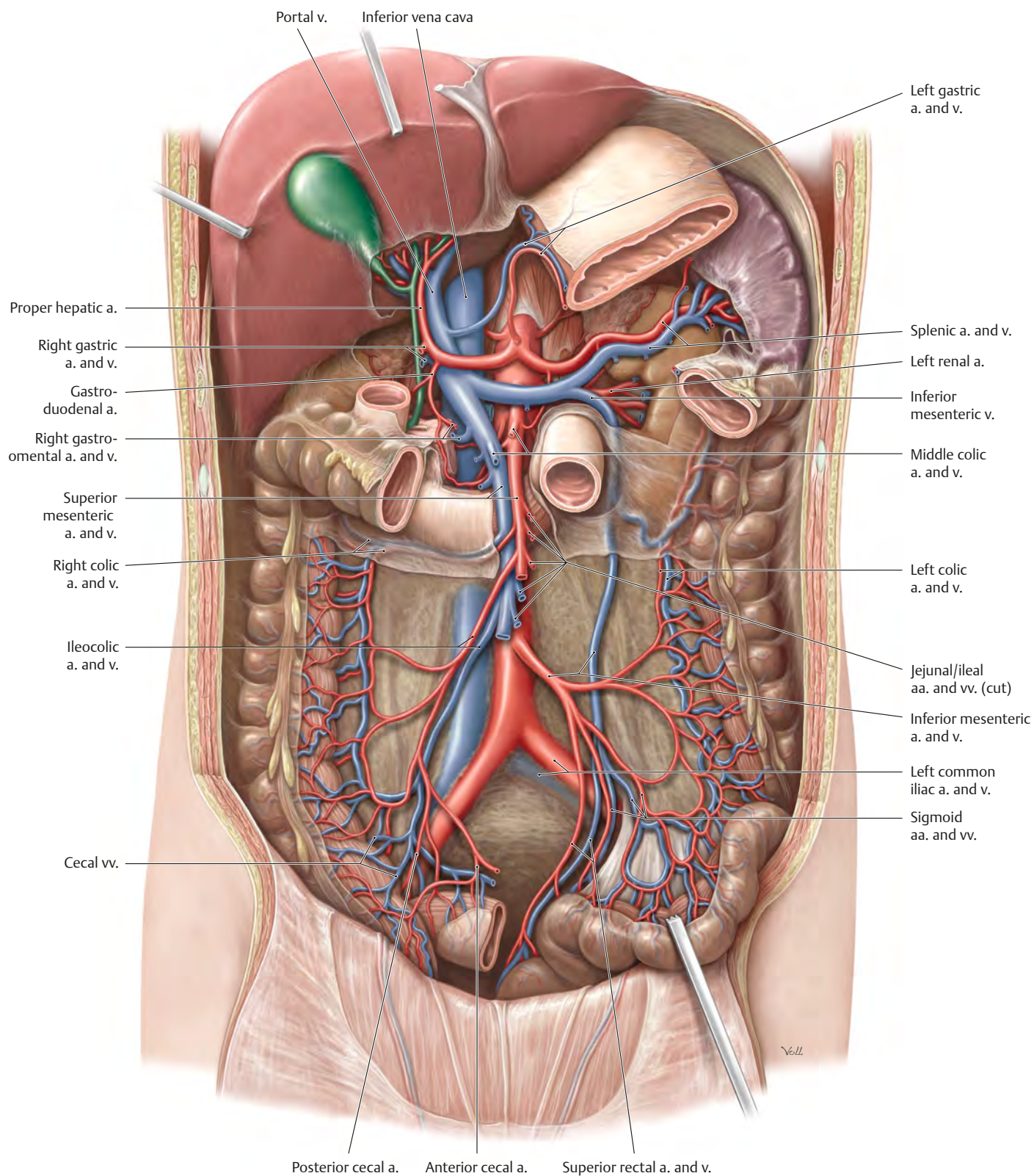


Fig. 16.21 Inferior mesenteric vein

Anterior view. *Partially removed:* Stomach, duodenum, and peritoneum. *Removed:* Pancreas, greater omentum, transverse colon, and small intestine. *Reflected:* Liver and gallbladder. The inferior mesenteric vein drains a smaller territory than the superior mesenteric vein. It receives tributaries from the distal transverse colon, descending and sigmoid colons and upper rectum. It ascends in the retroperitoneum, separate

from the artery, and generally joins with the splenic vein posterior to the stomach and pancreas. Note that the ascending and descending colons may also be drained by lumbar veins in the retroperitoneum, which empty into the inferior vena cava, constituting a portocaval collateral pathway.



Lymphatics of the Abdominal Wall & Organs

Fig. 16.22 Lymphatic drainage of the anterior trunk wall
Lymph from the skin of the trunk wall is collected mainly by the axillary and superficial inguinal lymph nodes (arrows indicate direction of lymph flow). A curved line that lies between the umbilicus and costal arch defines the “watershed” zone between the two drainages. Lymph from the right upper quadrant (green) is drained by the right lymphatic duct. Lymph from the remainder of the body (blue) is drained by the thoracic duct.

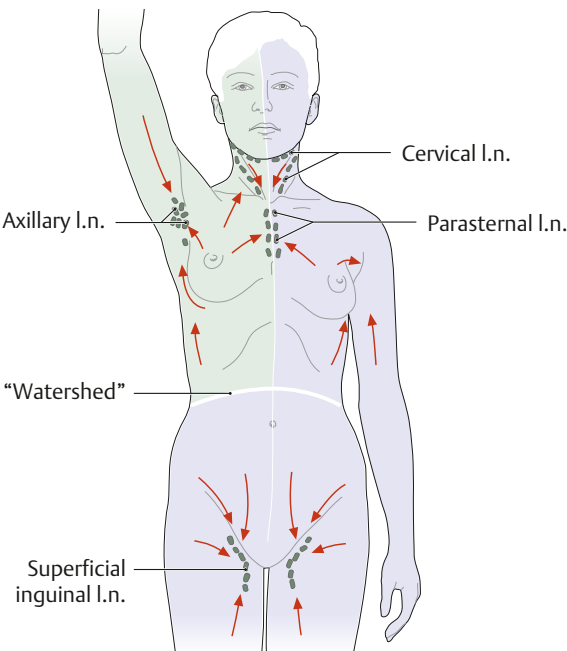


Fig. 16.23 Lymphatic drainage of the internal organs
See Table 16.3 for numbering. Lymph drainage from the abdomen, pelvis, and lower limb ultimately passes through the lumbar lymph nodes (clinically, the aortic nodes), which consist of the right lateral aortic (caval) and left lateral aortic nodes, the preaortic nodes, and the retroaortic nodes. Efferent lymph vessels from the lateral aortic, retroaortic, and inferior mesenteric nodes form the lumbar trunks. Those from the remaining preaortic nodes form the intestinal trunks. The lumbar and intestinal trunks terminate in the cisterna chyli.

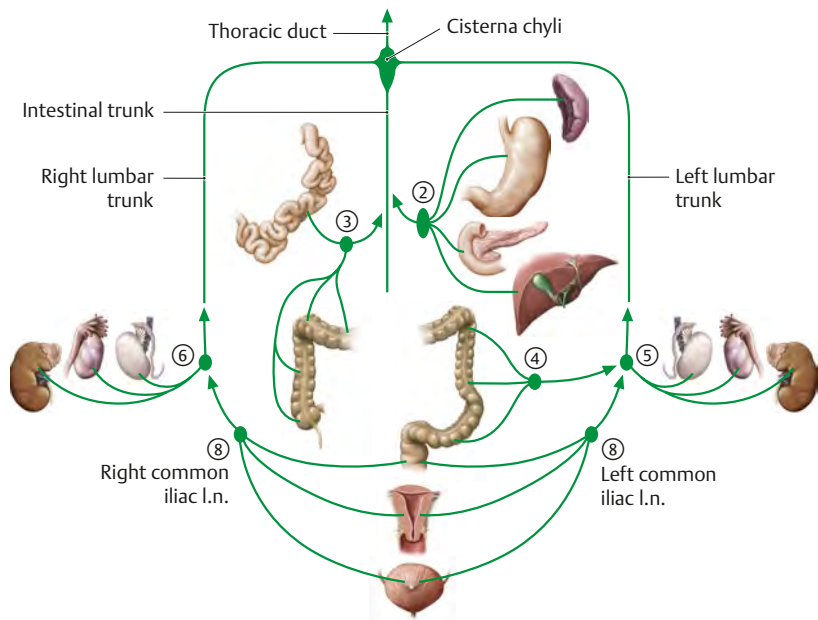


Table 16.3		Parietal lymph nodes of the abdomen
Lumbar l.n.	Preaortic l.n.	① Inferior phrenic l.n.
		② Celiac l.n.
		③ Superior mesenteric l.n.
		④ Inferior mesenteric l.n.
	Lateral aortic l.n.	⑤ Left lateral aortic l.n.
		⑥ Right lateral aortic (caval) l.n.
		⑦ Retroaortic l.n.
	⑧ Common iliac l.n.	

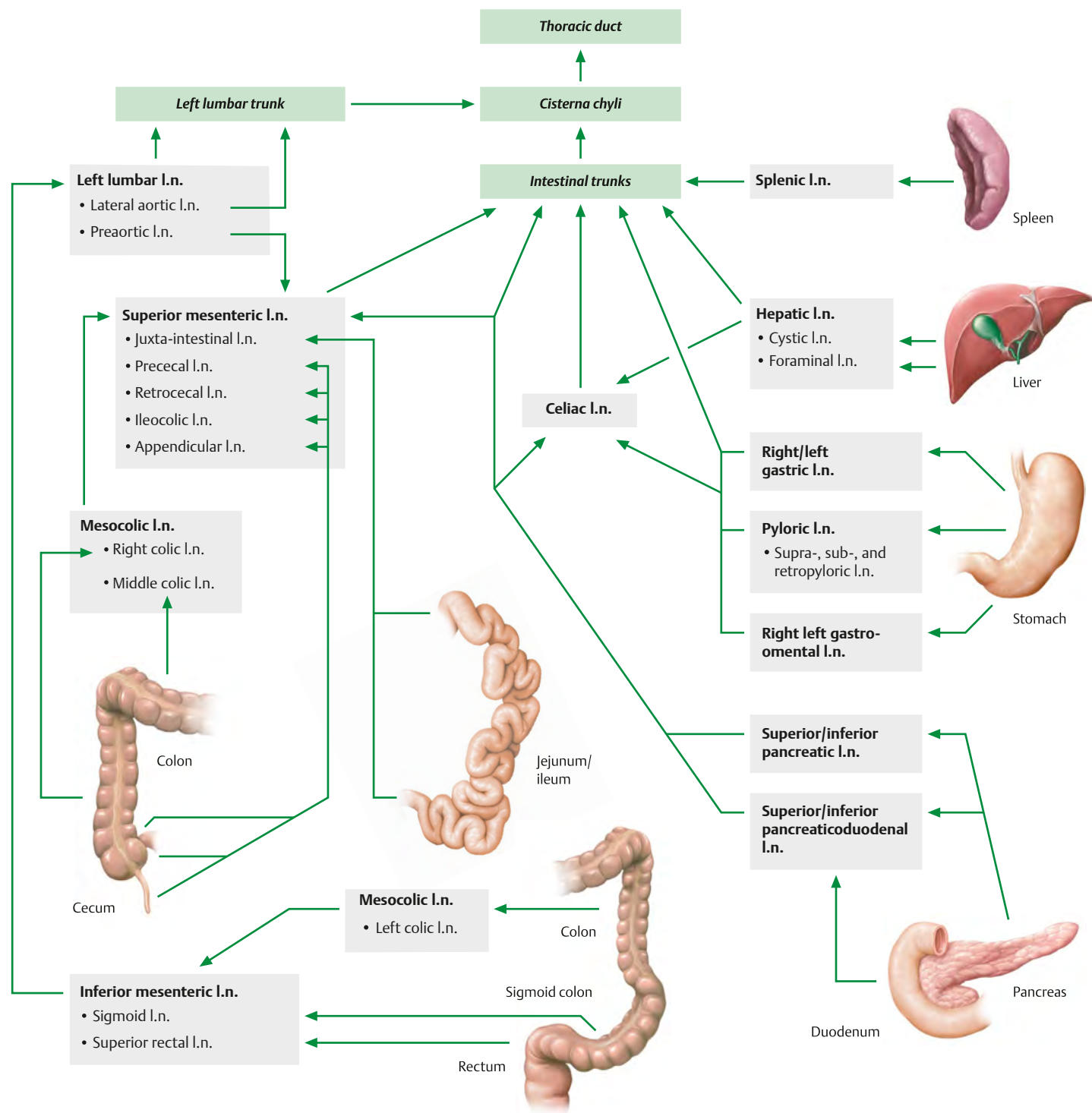


Fig. 16.24 Principal lymphatic pathways draining the digestive organs and spleen

Lymph from the spleen and most digestive organs drains directly from regional lymph nodes or through intervening collecting nodes to the intestinal trunks, except for the descending and sigmoid colon and the upper part of the rectum, which are drained by the left lumbar trunk.

The three large collecting nodes are:

- *Celiac lymph nodes* collect lymph from the stomach, duodenum, pancreas, spleen, and liver. Topographically and at dissection they are often indistinguishable from the regional lymph nodes of the nearby upper abdominal organs.

- *Superior mesenteric lymph nodes* collect lymph from the jejunum, ileum, ascending and transverse colon.
- *Inferior mesenteric lymph nodes* collect lymph from the descending and sigmoid colon and rectum.

These nodes drain principally through the intestinal trunks to the cisterna chyli, but there is an accessory drainage route by way of the left lumbar lymph nodes. Lymph from the pelvis also drains up into the inferior mesenteric and lateral aortic lymph nodes. A complete drainage pathway for lymph from the pelvis can be found on **p. 276**.

Lymph Nodes of the Posterior Abdominal Wall

Lymph nodes in the abdomen and pelvis may be classified as either parietal or visceral. The majority of the parietal lymph nodes are located on the posterior abdominal wall.

Fig. 16.25 Parietal lymph nodes in the abdomen and pelvis

Anterior view. *Removed:* All visceral structures except vessels.

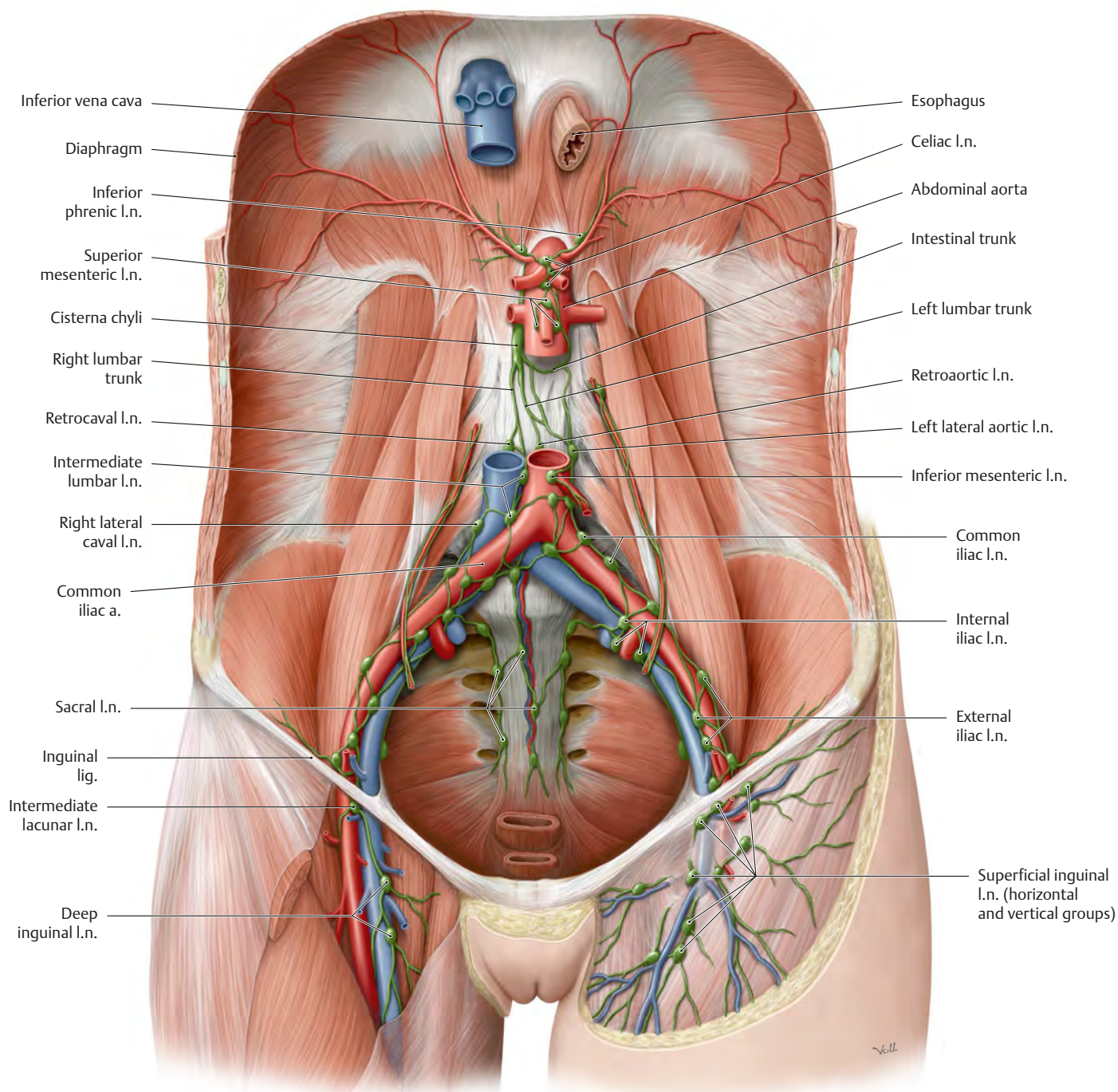


Fig. 16.26 Lymph nodes of the kidneys, ureters, and suprarenal glands
Anterior view.

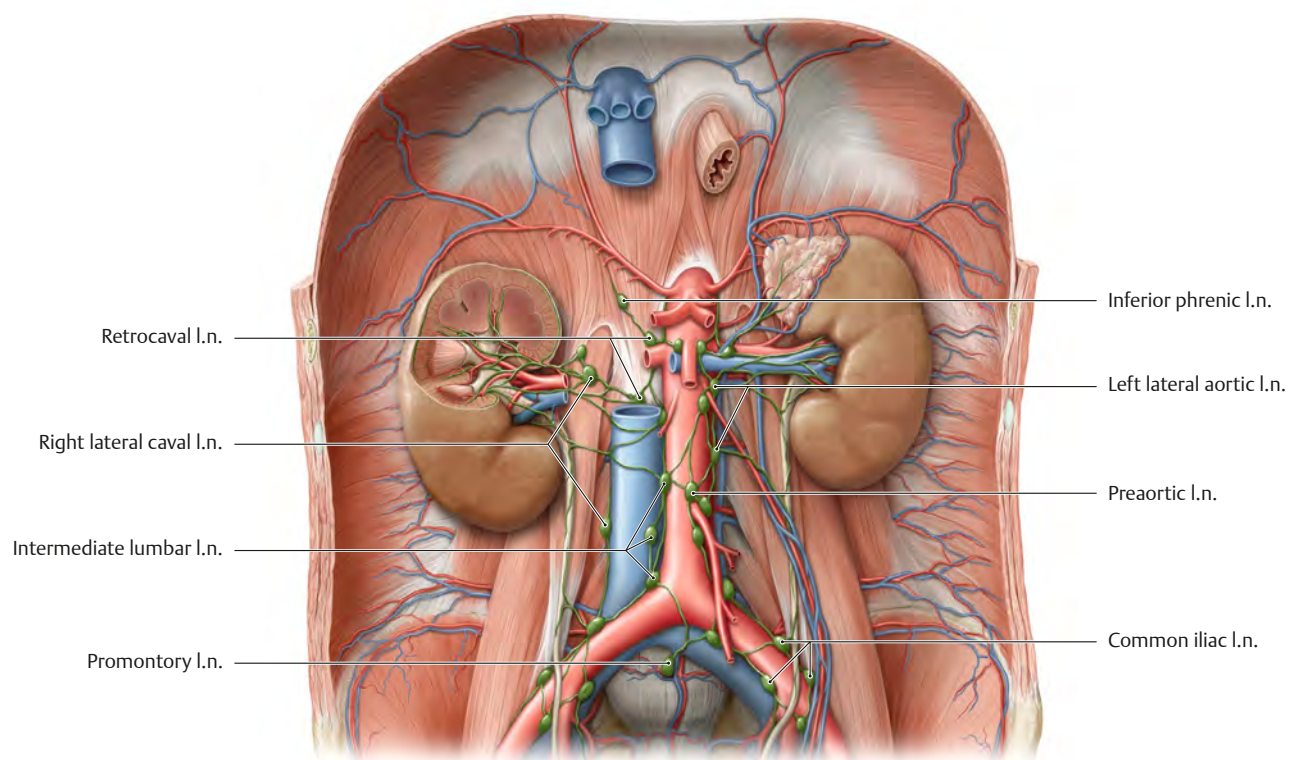
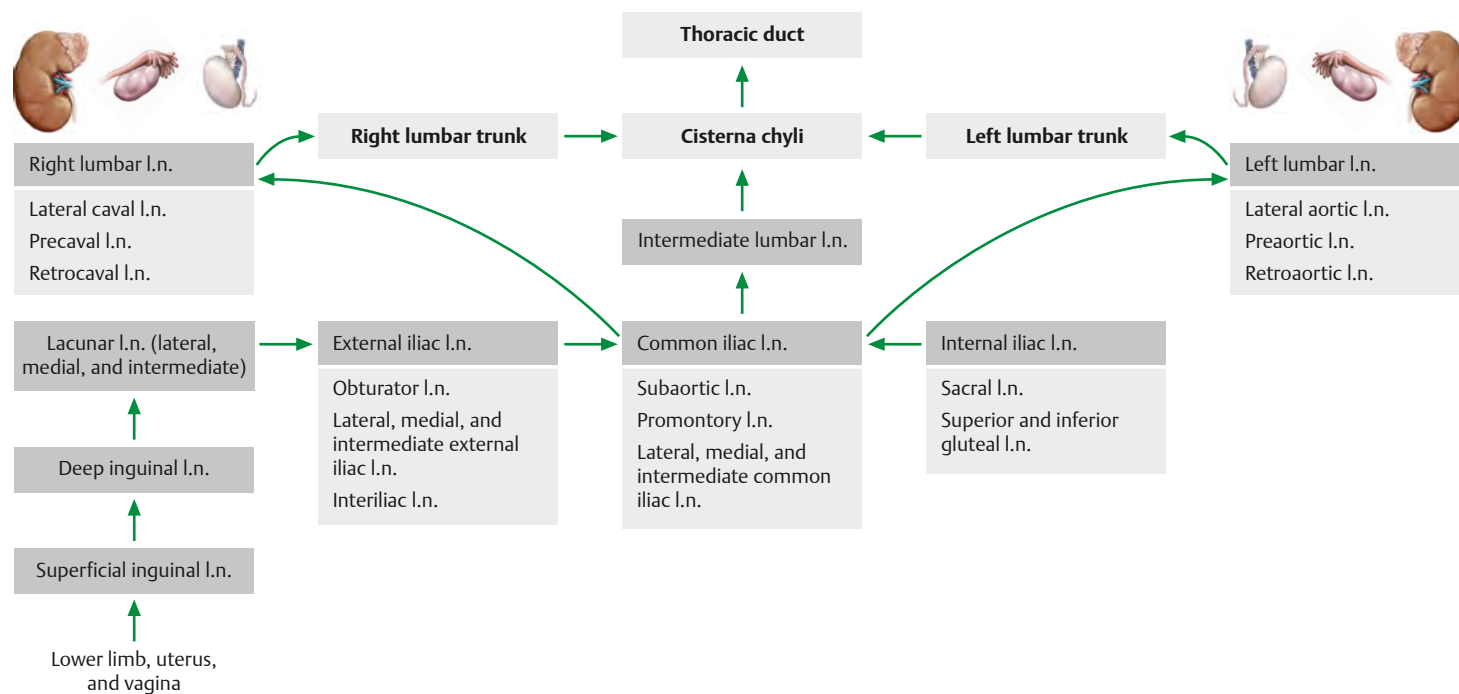


Fig. 16.27 Lymphatic drainage of the kidneys and gonads (with pelvic organs)



Lymph Nodes of the Supracolic Organs

Fig. 16.28 Lymph nodes of the stomach and liver

Anterior view. *Removed:* Lesser omentum. *Opened:* Greater omentum. Arrows show direction of lymphatic drainage.

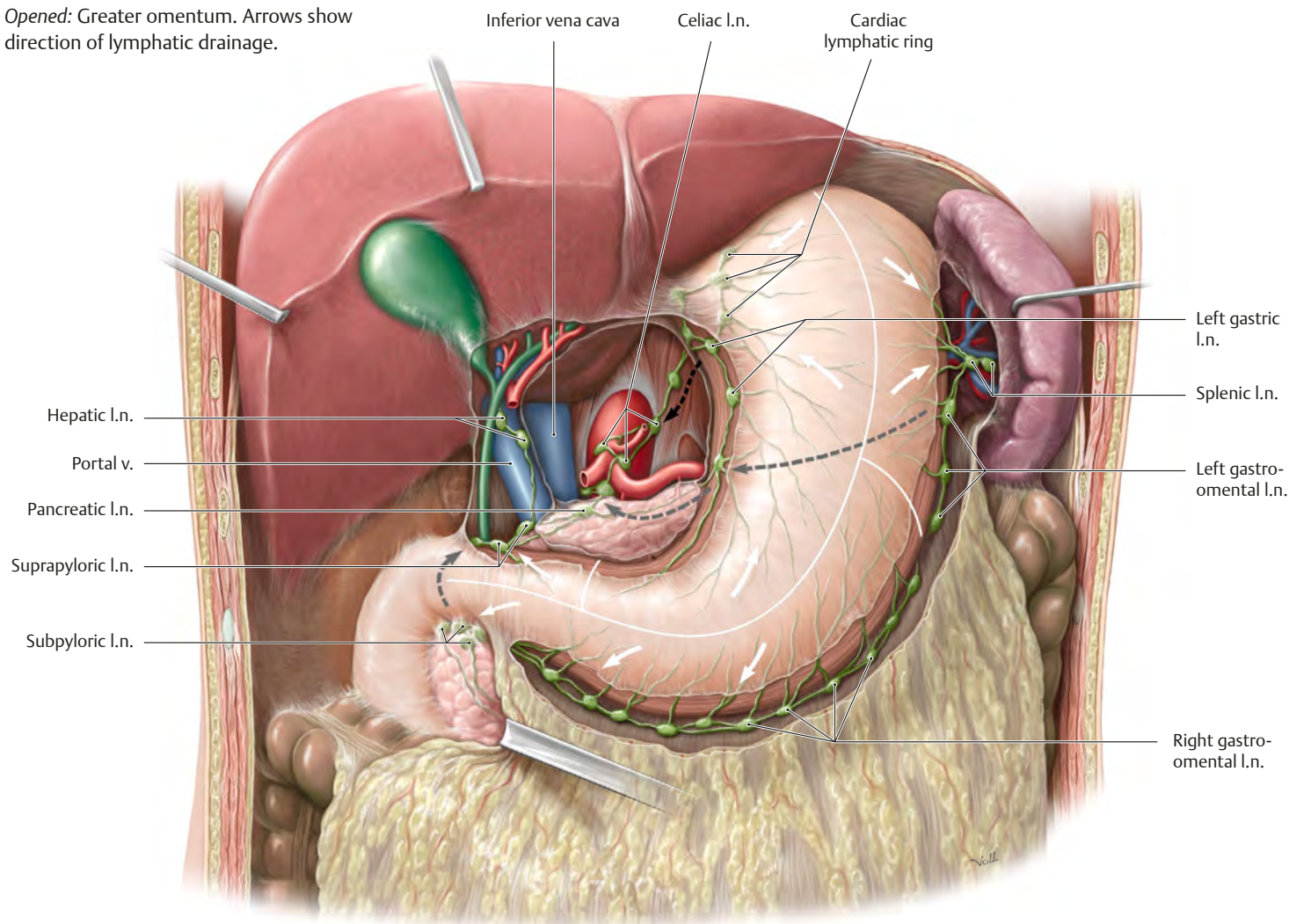


Fig. 16.29 Lymphatic drainage of the liver and biliary tract

Anterior view. In the region of the liver, the major lymph-producing organ, the important pathways are:

- **Liver and intrahepatic bile ducts:** Most lymph drains inferiorly through the hepatic nodes to the celiac nodes and then to the intestinal trunk and cisterna chyli, but it may take a more direct route bypassing the celiac nodes. A small amount drains cranially through the inferior phrenic nodes to the lumbar trunk. It also can drain through the diaphragm to the superior phrenic nodes and on to the bronchomediastinal trunk.
- **Gallbladder:** Lymph drains initially to the cystic node, then follows one of the pathways described above.
- **Common bile duct:** Lymph drains through the pyloric nodes (supra-, sub-, and retropyloric) and the foraminal node to the celiac nodes, then to the intestinal trunk.

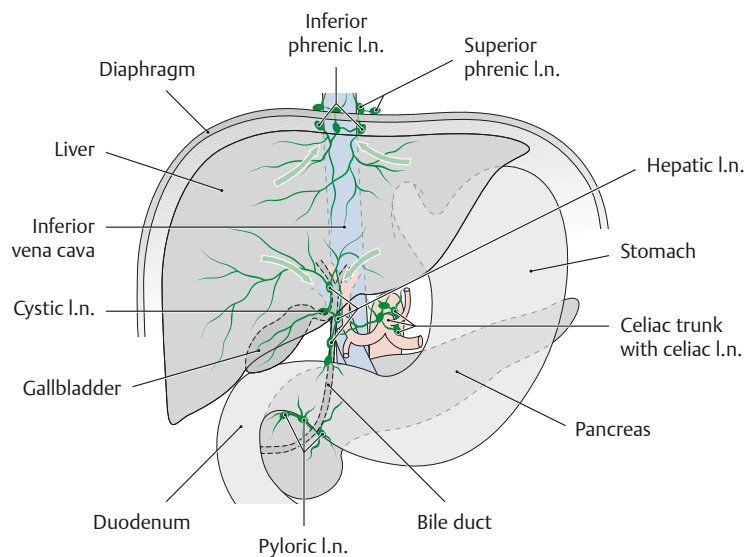


Fig. 16.30 Lymph nodes of the spleen, pancreas, and duodenum

Anterior view. *Removed:* Stomach and colon.

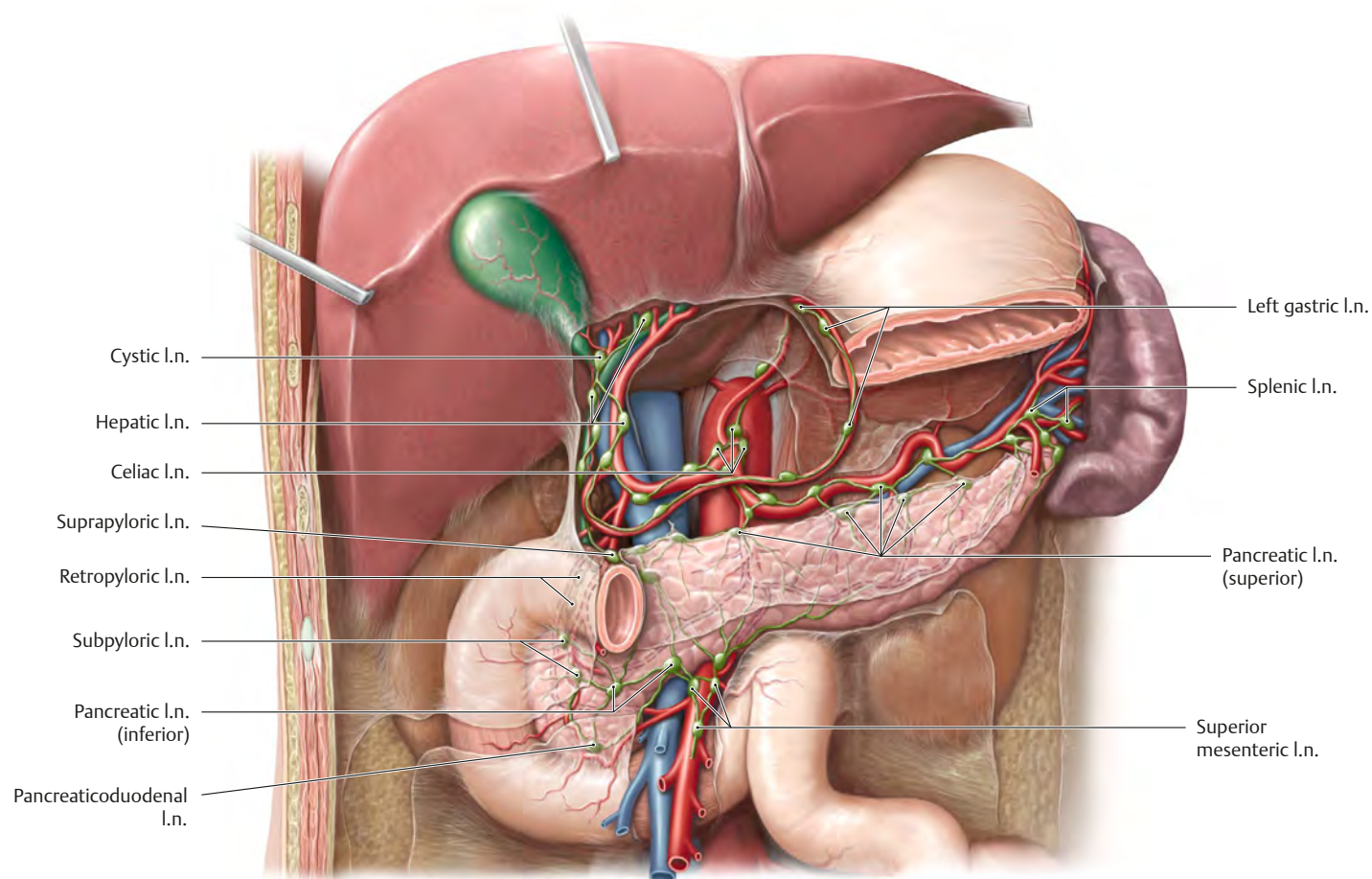
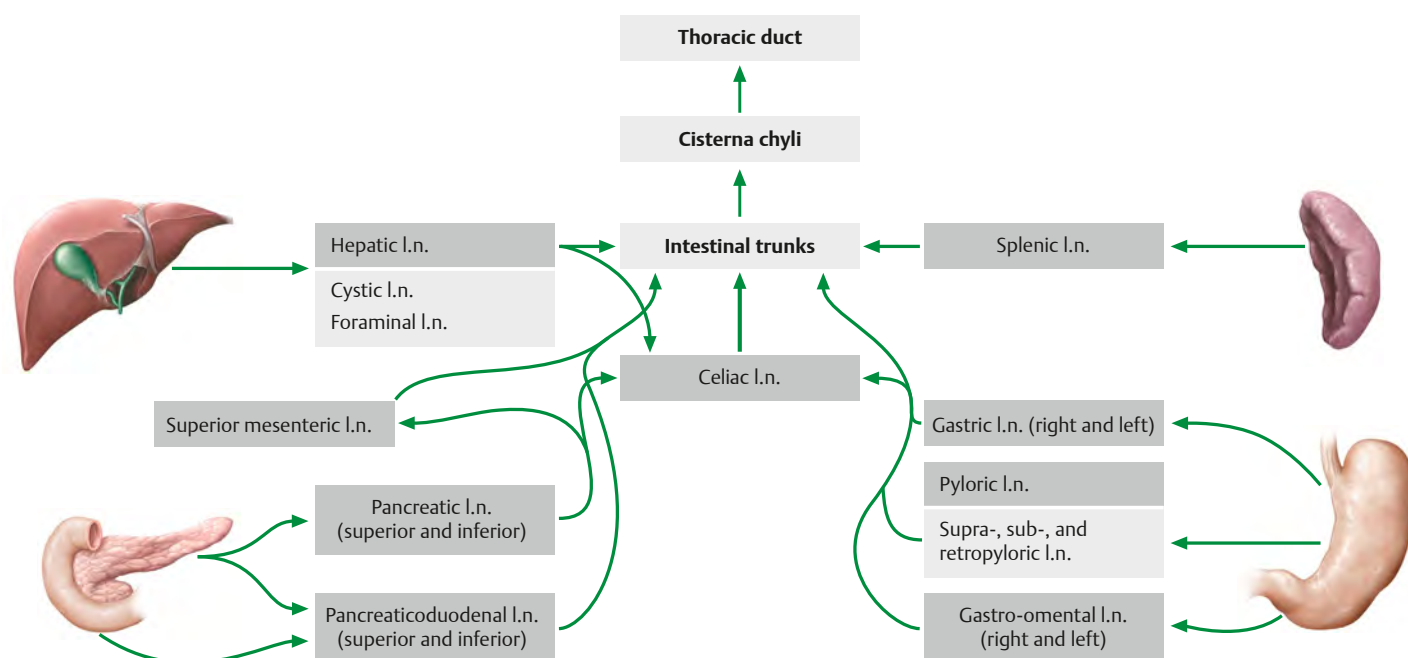


Fig. 16.31 Lymphatic drainage of the stomach, liver, spleen, pancreas, and duodenum



Lymph Nodes of the Infracolic Organs

Fig. 16.32 Lymph nodes of the jejunum and ileum
Anterior view. *Removed:* Stomach, liver, pancreas, and colon.

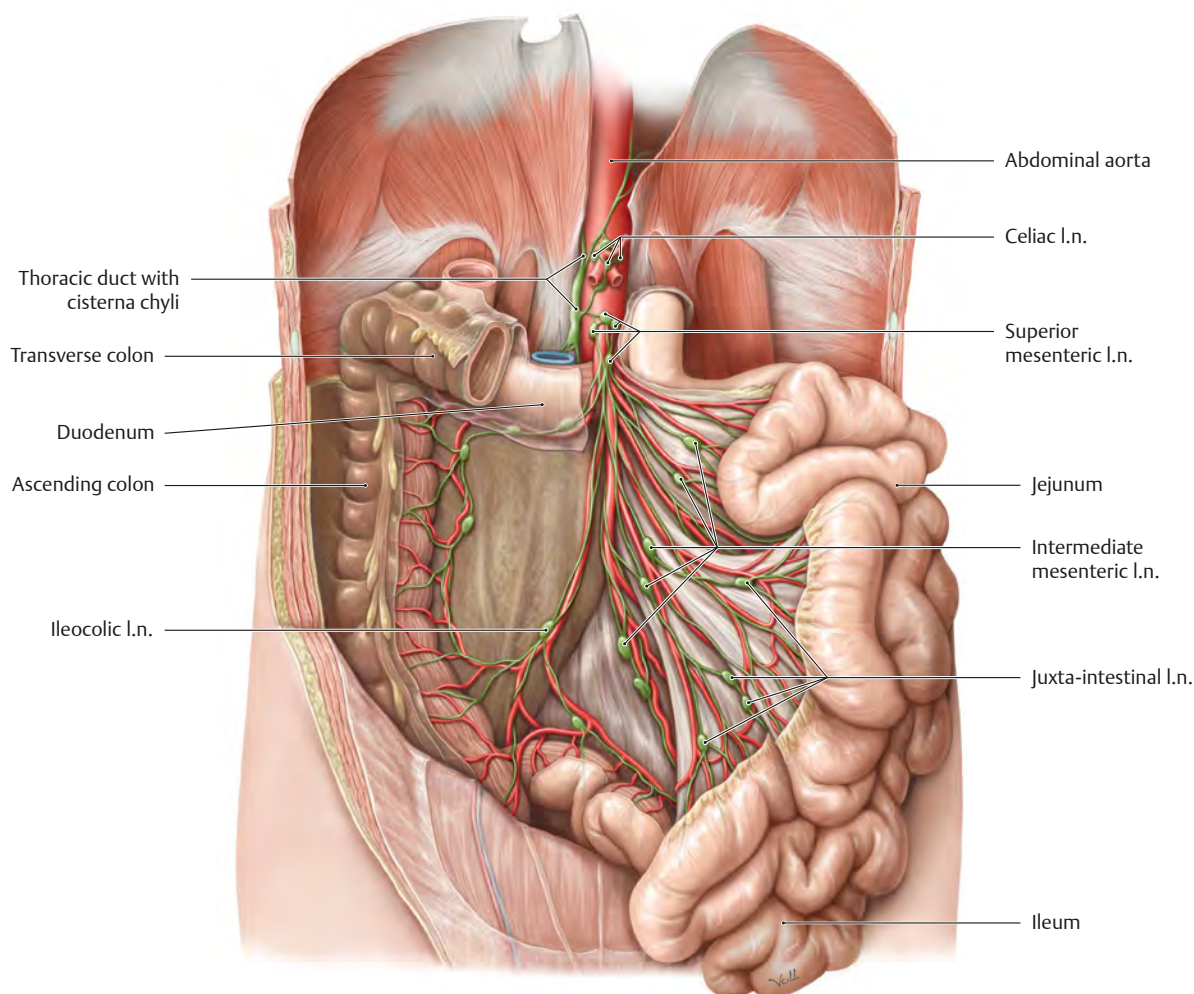


Fig. 16.33 Lymphatic drainage of the intestines

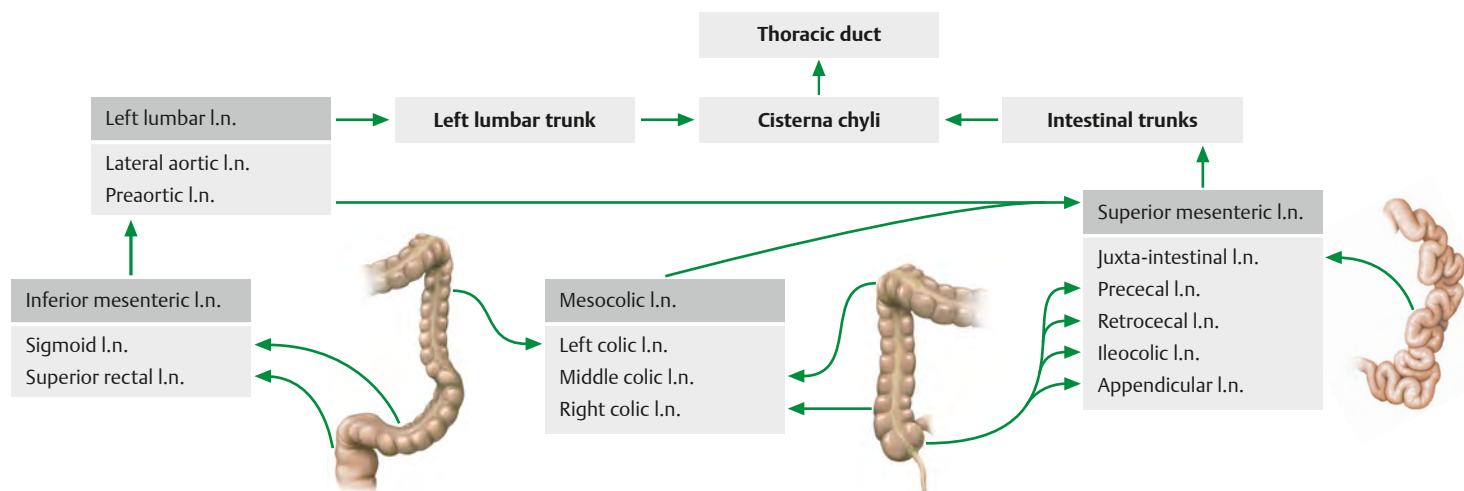
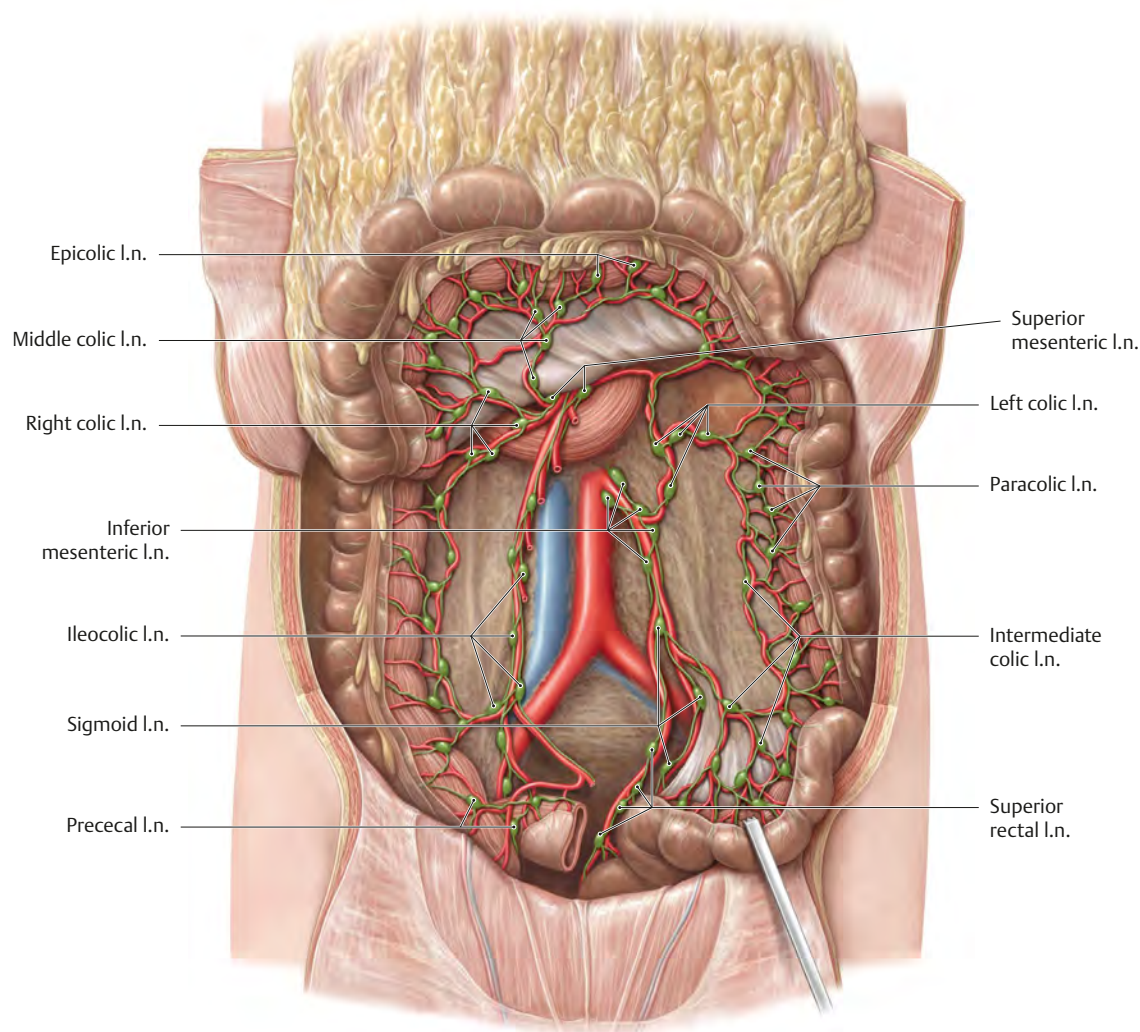


Fig. 16.34 Lymph nodes of the large intestineAnterior view. *Reflected:* Transverse colon and greater omentum.**Clinical box 16.8****Lymphatic drainage of the large intestine**

Regional lymphatic pathways in the large intestine have important clinical affects.

- **Ascending colon, cecum, and transverse colon:** Lymph drains initially to the *right and middle colic nodes*, then to the *superior mesenteric nodes*, and finally to the *intestinal trunk*.
- **Descending colon:** Lymph drains initially to the regional *left colic nodes*, then to the *inferior mesenteric nodes*, then via the *left lumbar nodes* into the *left lumbar trunk*.
- **Sigmoid colon:** Lymph drains initially to *sigmoid nodes* then follows the pathway described above for the descending colon.

- **Upper rectum:** Lymph drains initially to the *superior rectal nodes* then follows the pathway described above for the sigmoid colon.

Thus, a malignant tumor undergoing lymphogenous spread must negotiate several lymph node groups (all of which should be removed in tumor resections) before the malignant cells can reach the intestinal trunk and thoracic duct and finally enter the bloodstream. This long route of lymphogenous spread improves the prospects for a cure.

Nerves of the Abdominal Wall

Fig. 16.35 Somatic nerves of the abdomen and pelvis

Anterior view. The abdominal wall is innervated by somatic nerves that include the lower intercostal nerves and branches of the lumbar plexus.

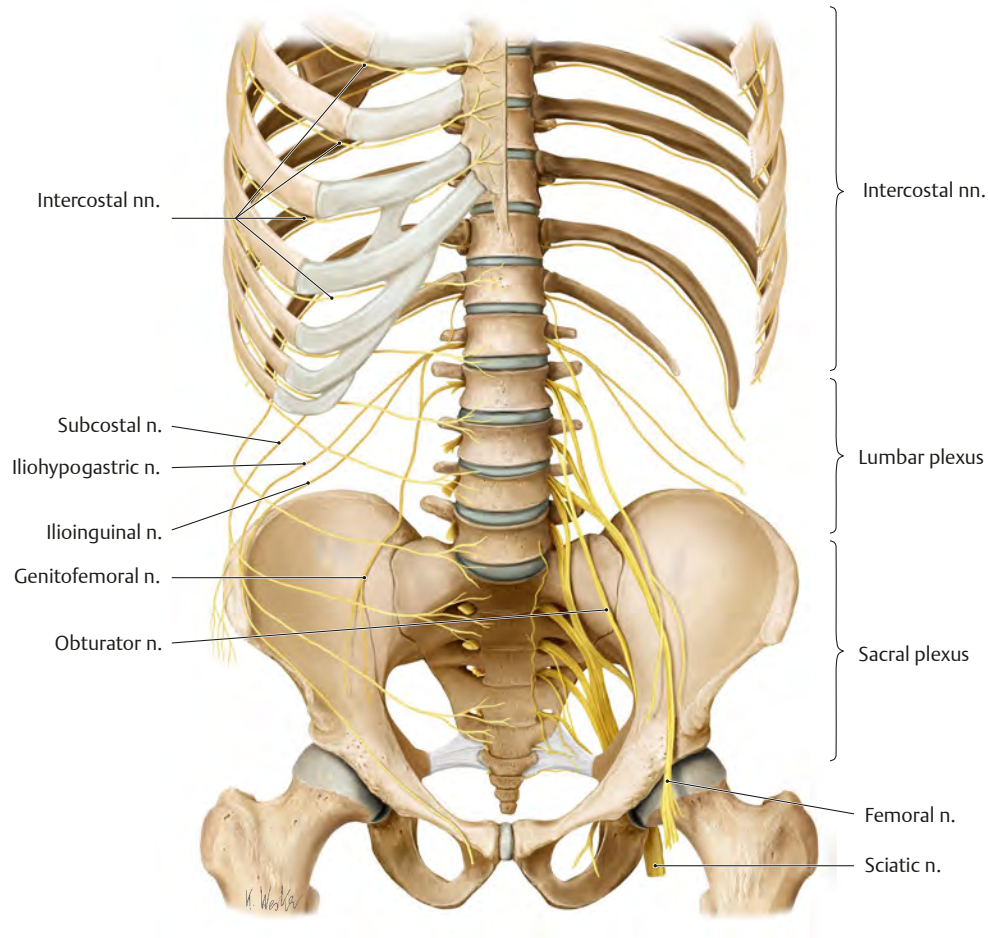


Fig. 16.36 Cutaneous innervation of the anterior trunk
Anterior view.

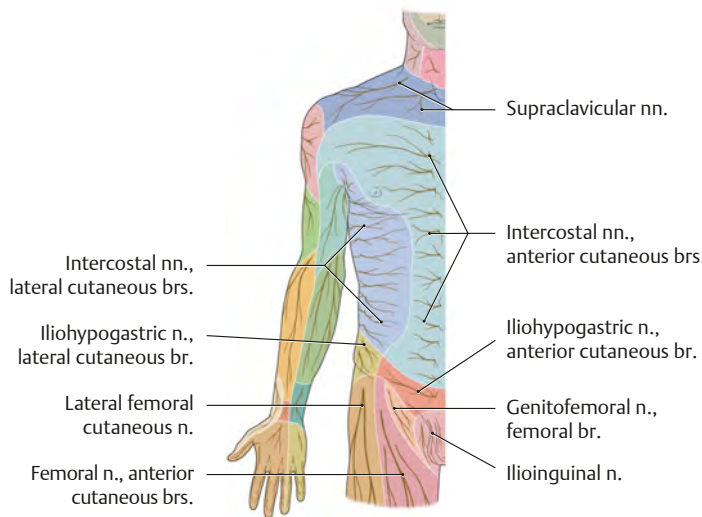


Fig. 16.37 Dermatomes of the anterior trunk
Anterior view.

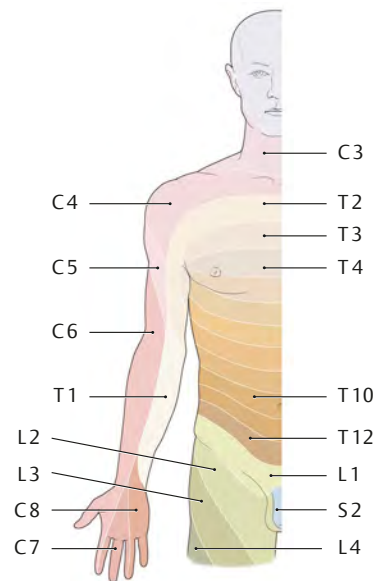
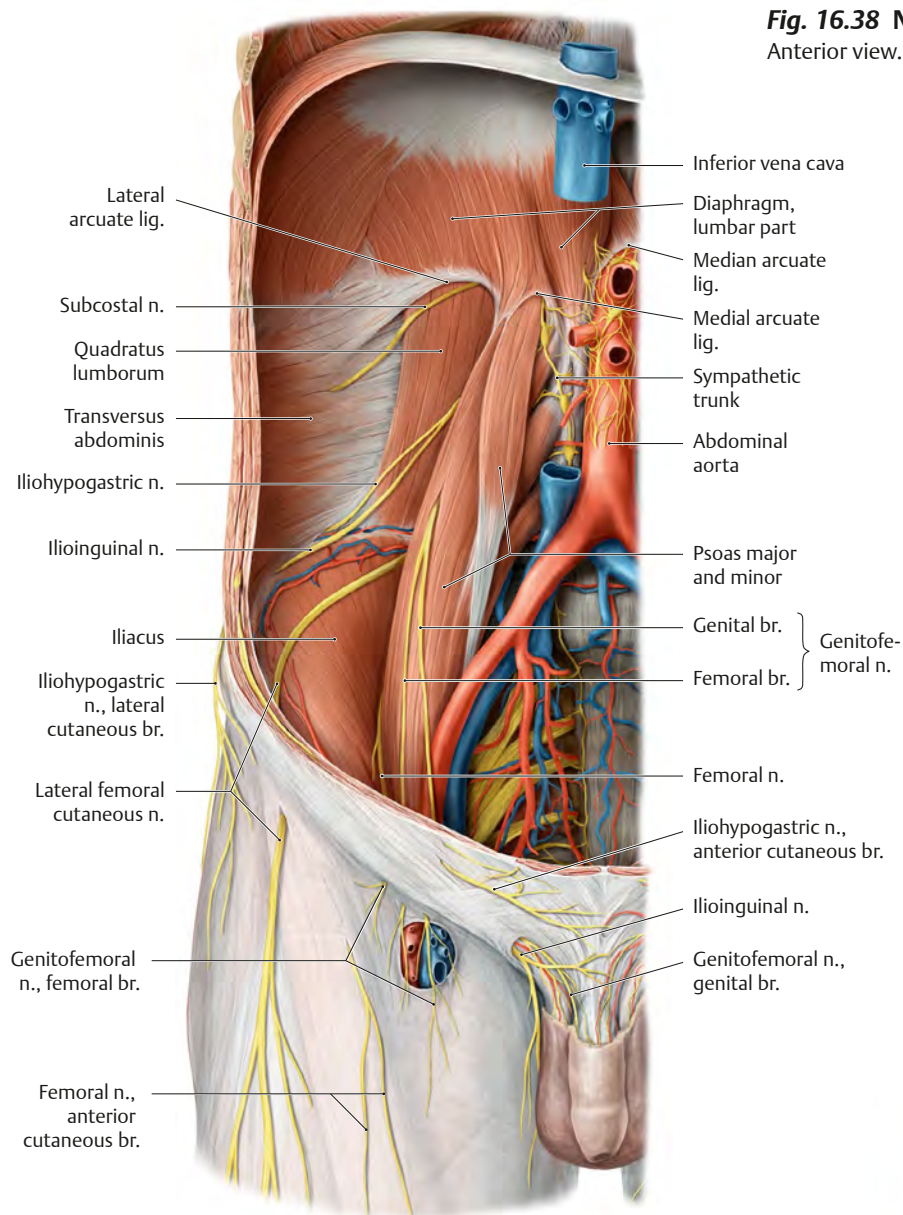
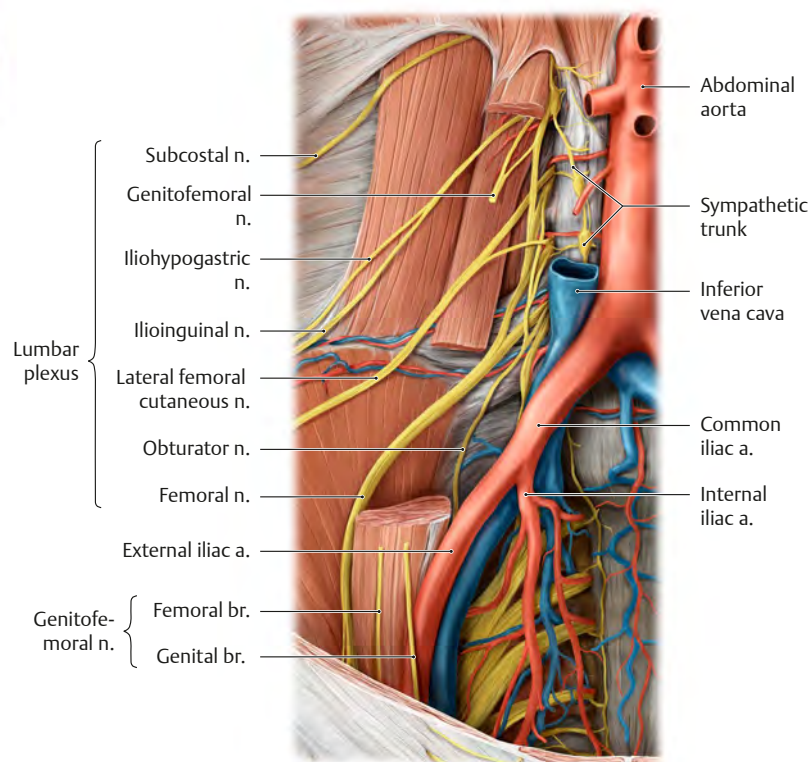


Fig. 16.38 Nerves of the lumbar plexus
Anterior view.



A Lumbar plexus in situ. *Removed:*
All visceral structures except vessels.



B Lumbar plexus, dissection.
Windowed: Psoas major and minor muscles.

Autonomic Innervation: Overview

Fig. 16.39 Sympathetic and parasympathetic nervous systems in the abdomen and pelvis

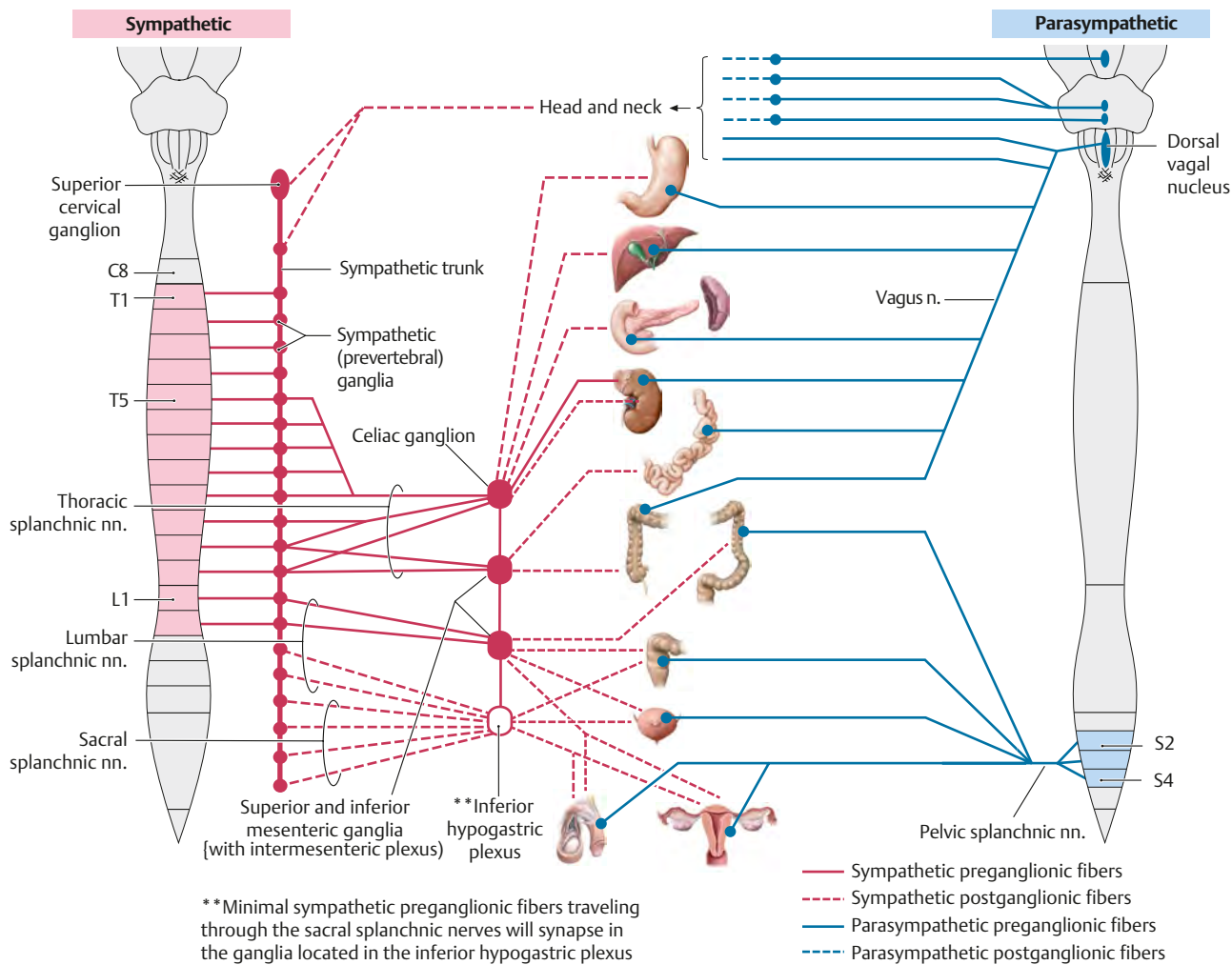


Table 16.4 Effects of the autonomic nervous system in the abdomen and pelvis			
Organ (organ system)		Sympathetic effect	Parasympathetic effect
Gastrointestinal tract	Longitudinal and circular muscle fibers	↓ motility	↑ motility
	Sphincter muscles	Contraction	Relaxation
	Glands	↓ secretions	↑ secretions
Splenic capsule		Contraction	
Liver		↑ glycogenolysis/gluconeogenesis	No effect
Pancreas	Endocrine pancreas	↓ insulin secretion	
	Exocrine pancreas	↓ secretion	↑ secretion
Urinary bladder	Detrusor vesicae	Relaxation	Contraction
	Functional bladder sphincter	Contraction	Inhibits contraction
Seminal glands and ductus deferens		Contraction (ejaculation)	
Uterus		Contraction or relaxation, depending on hormonal status	No effect
Arteries		Vasoconstriction	Vasodilation of the arteries of the penis and clitoris (erection)
Suprarenal glands (medulla)		Release of adrenalin	No effect
Urinary tract	Kidney	Vasoconstriction (↓ urine formation)	Vasodilation

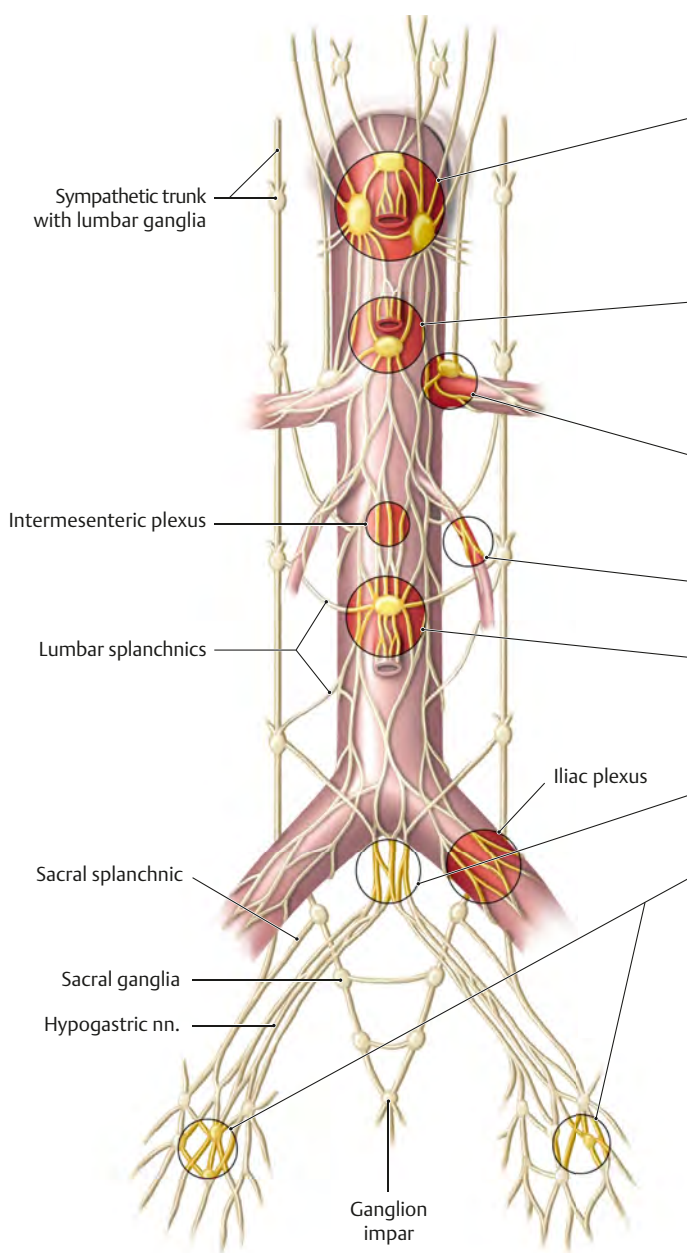


Table 16.5

Autonomic plexuses in the abdomen and pelvis

Ganglia	Subplexus	Distribution	
Celiac plexus			
Celiac ganglia	Hepatic plexus	• Liver, gallbladder	
	Gastric plexus	• Stomach	
	Splenic plexus	• Spleen	
	Pancreatic plexus	• Pancreas	
Superior mesenteric plexus			
Superior mesenteric ganglion	—	• Pancreas (head) • Duodenum • Jejunum • Ileum	• Cecum • Colon (to left colic flexure) • Ovary
Suprarenal and renal plexus			
Aorticorenal ganglion	Ureteral plexus	• Suprarenal gland • Kidney • Proximal ureter	
Ovarian/testicular plexus			
—	—	• Ovary/testis	
Inferior mesenteric plexus			
Inferior mesenteric ganglion	Left colic plexus	• Left colic flexure	
	Superior rectal plexus	• Descending and sigmoid colon • Upper rectum	
Superior hypogastric plexus			
—	Hypogastric nn.	• Pelvic viscera	
Inferior hypogastric plexus			
Pelvic ganglia	Middle and inferior rectal plexus	• Middle and lower rectum	
	Prostatic plexus	• Prostate • Seminal gland • Bulbourethral gland	• Ejaculatory duct • Penis • Urethra
	Deferential plexus	• Ductus deferens • Epididymis	
	Uterovaginal plexus	• Uterus • Uterine tube	• Vagina • Ovary
	Vesical plexus	• Urinary bladder	
	Ureteral plexus	• Ureter (ascending from pelvis)	
	—	• Middle and lower rectum	

Note: The two sacral sympathetic trunks converge and terminate in front of the coccyx in a small ganglion, the ganglion impar.

Autonomic Innervation & Referred Pain

Pain afferents from the viscera (visceral pain) and dermatomes (somatic pain) terminate at the same processing neurons in the posterior horn of the spinal cord. The convergence of these visceral and somatic afferent fibers confuses the relationship between the pain's origin and its

perception. This phenomenon is called *referred pain*. The pain impulses from a particular internal organ are consistently projected to the same well-defined skin area. Thus, the area of skin that the pain is projected to provides crucial information regarding what organ is affected.

Fig. 16.40 Autonomic innervation of the liver, gallbladder, and stomach

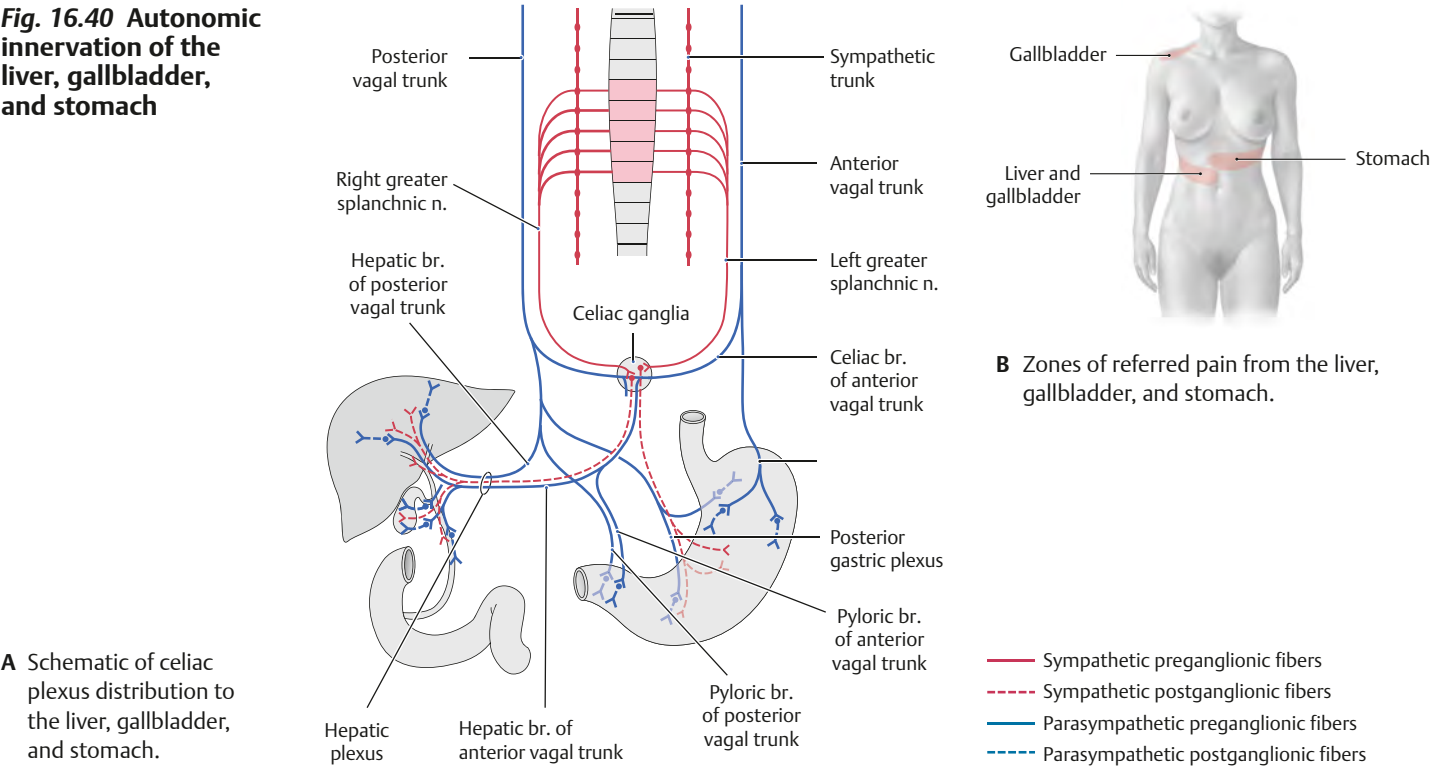


Fig. 16.41 Autonomic innervation of the pancreas, duodenum, and spleen

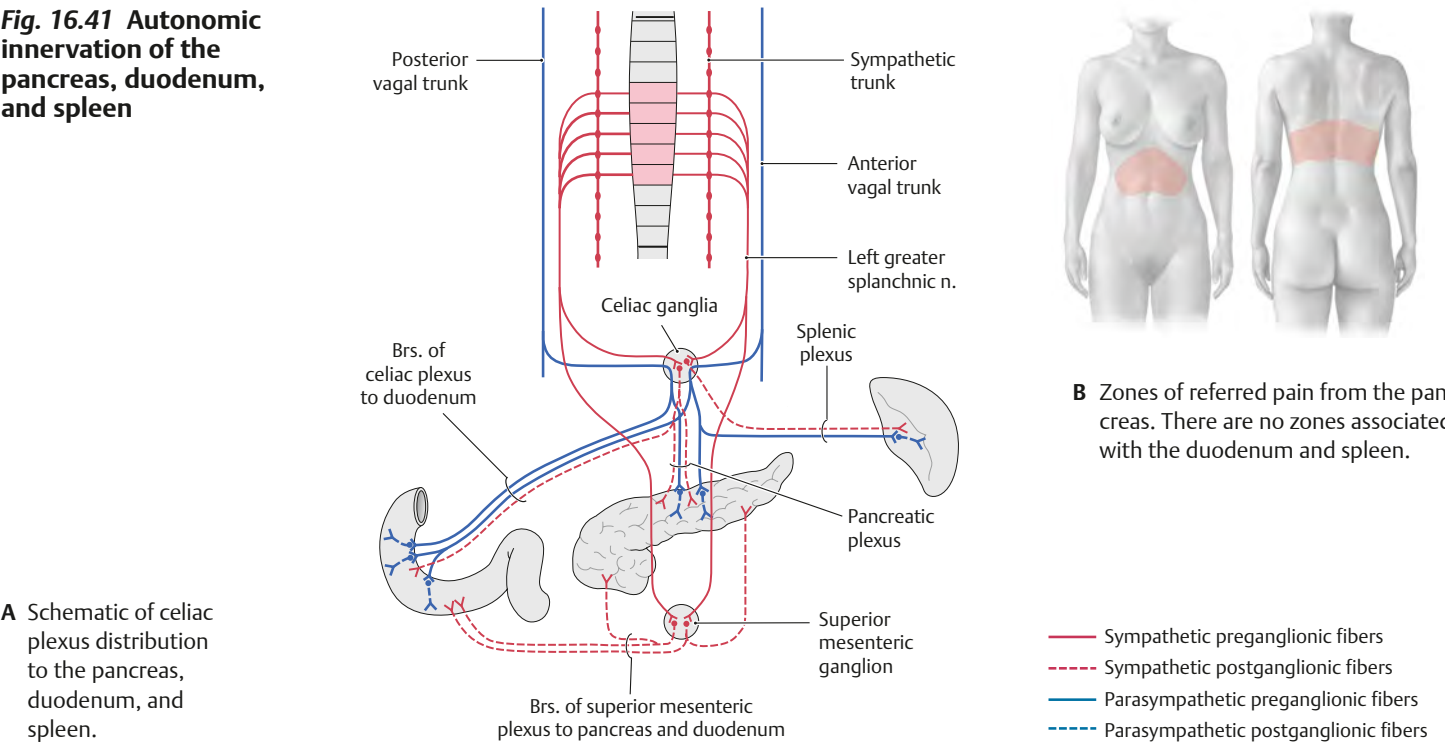
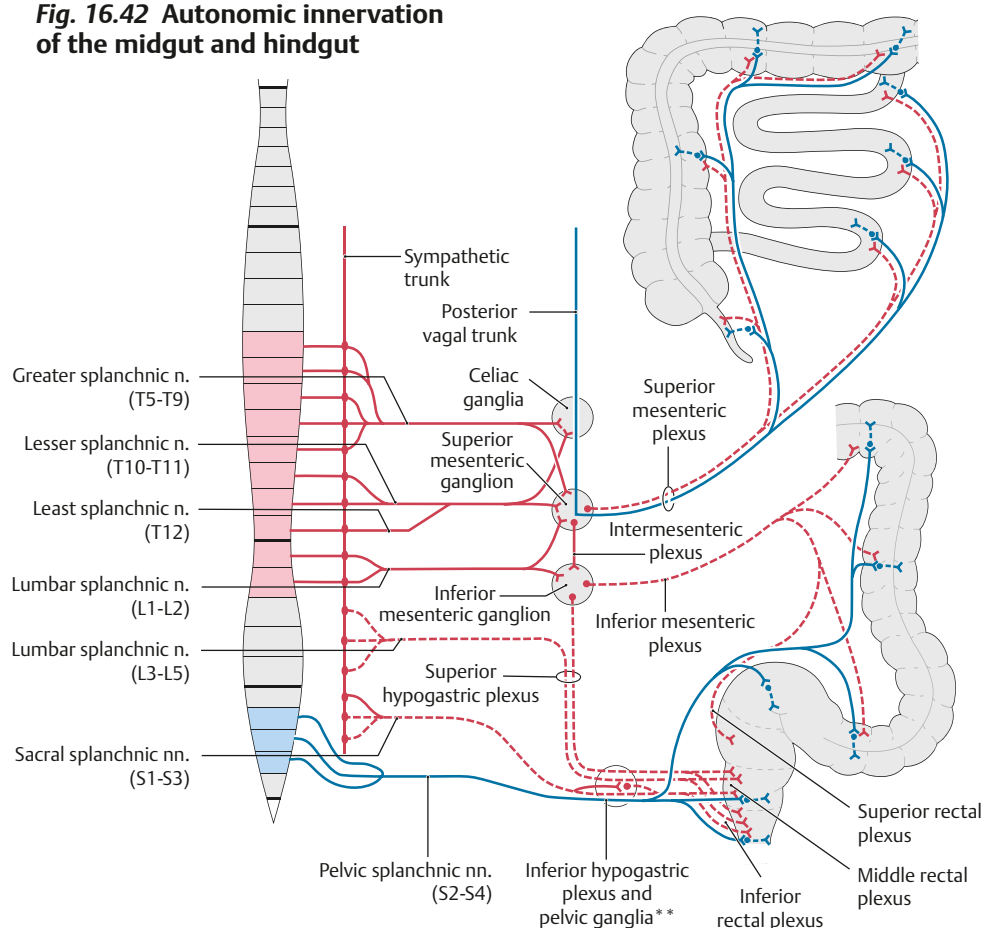
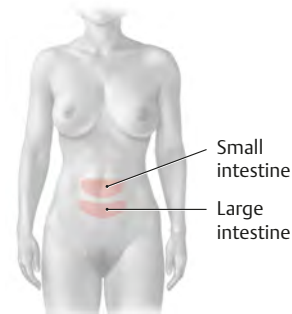


Fig. 16.42 Autonomic innervation of the midgut and hindgut



A Schematic of superior mesenteric, inferior mesenteric, and inferior hypogastric plexuses distribution.

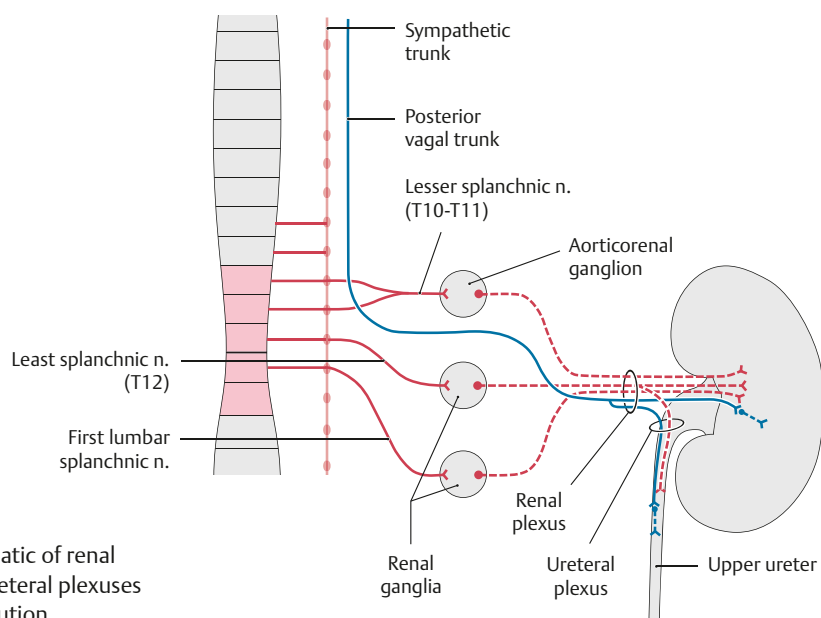


B Zones of referred pain from the small and large intestine.

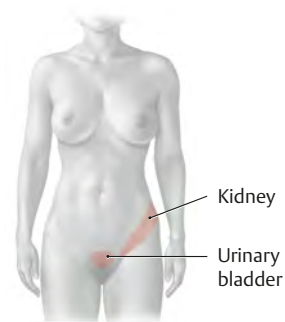
- Sympathetic preganglionic fibers
- - - Sympathetic postganglionic fibers
- Parasympathetic preganglionic fibers
- - - Parasympathetic postganglionic fibers

** Minimal sympathetic preganglionic fibers traveling through the sacral splanchnic nerves will synapse in the ganglia located in the inferior hypogastric plexus.

Fig. 16.43 Autonomic innervation of the kidneys and upper ureters



A Schematic of renal and ureteral plexuses distribution.



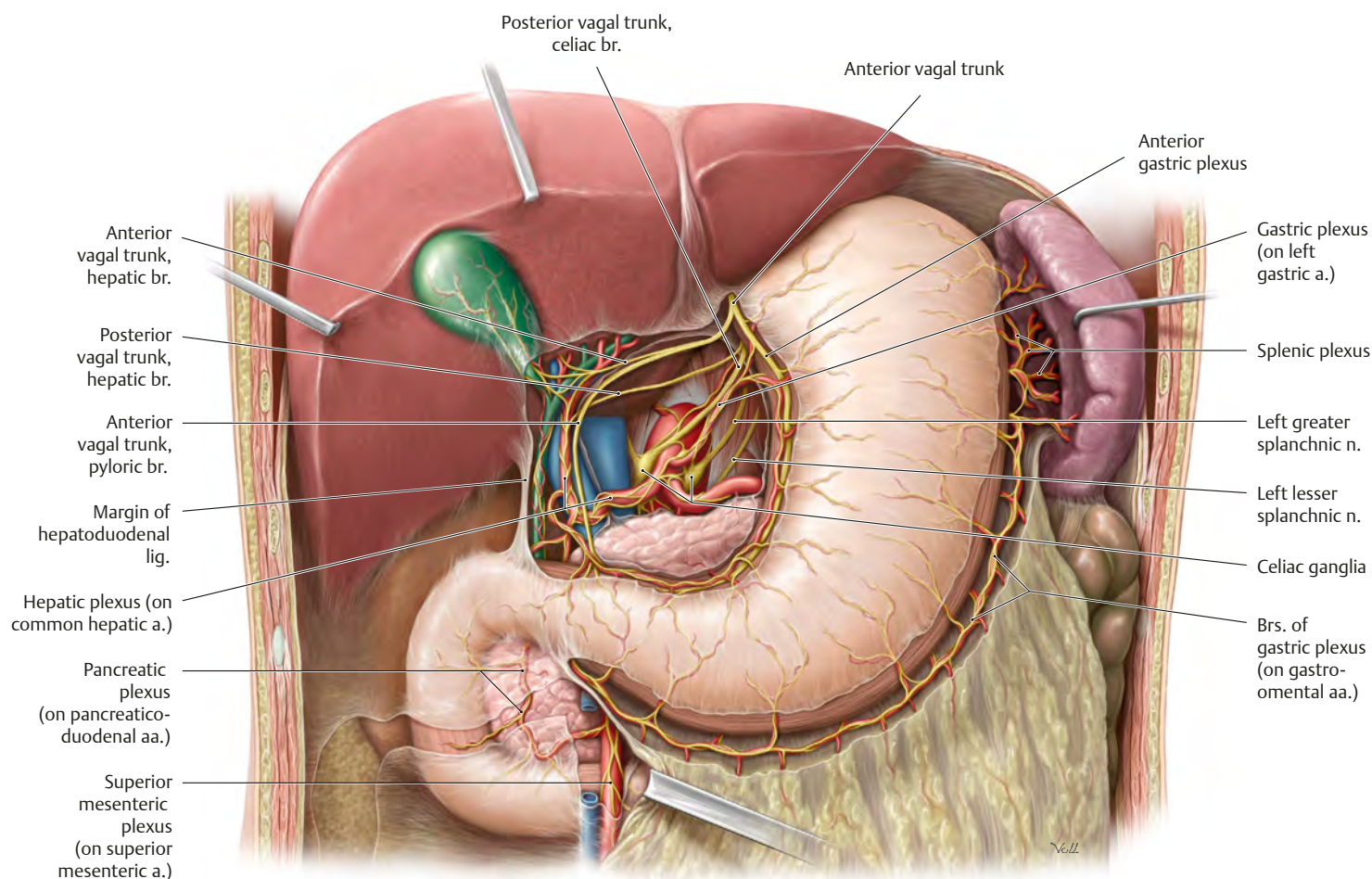
B Zones of referred pain from the left kidney and bladder.

- Sympathetic preganglionic fibers
- - - Sympathetic postganglionic fibers
- Parasympathetic preganglionic fibers
- - - Parasympathetic postganglionic fibers

Innervation of the Foregut & Urinary Organs

Fig. 16.44 Innervation of the foregut and spleen

Anterior view. *Removed:* Lesser omentum, ascending colon, and parts of the transverse colon. *Opened:* Omental bursa. The anterior and posterior vagal trunks each produce a celiac, hepatic, and pyloric branch, and a gastric plexus. See p. 214 for schematic.



Clinical box 16.9

Organization of the enteric plexus

The enteric plexus is the portion of the autonomic nervous system that specifically serves *all the organs of the gastrointestinal tract*. Located within the wall of the digestive tube (intramural nervous system), it is subject to both sympathetic and parasympathetic influences. Congenital absence of the enteric plexus leads to severe disturbances of gastrointestinal transit (e.g., Hirschsprung disease). The enteric plexus has basically the same organization throughout the gastrointestinal tract, although there is an area in the wall of the lower rectum that is devoid of ganglion cells. Three subsystems are distinguished in the enteric plexus:

- Submucosal plexus (Meissner's plexus)
- Myenteric plexus (Auerbach's plexus)
- Subserosal plexus

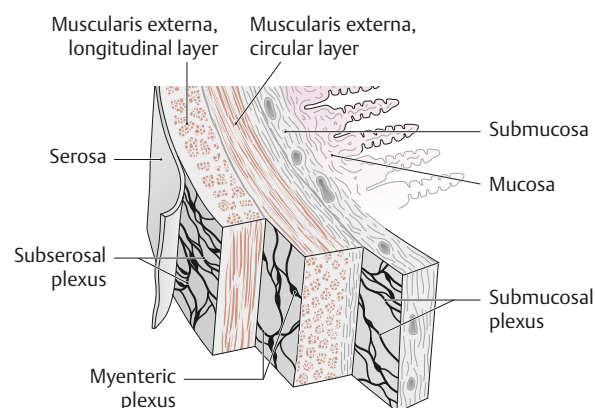


Fig. 16.45 Innervation of the urinary organs

Anterior view of the male abdomen and pelvis. *Removed:* Peritoneum, majority of stomach, and abdominal organs except kidneys, suprarenal glands, and bladder. See pp. 215 and 282 for schematic.

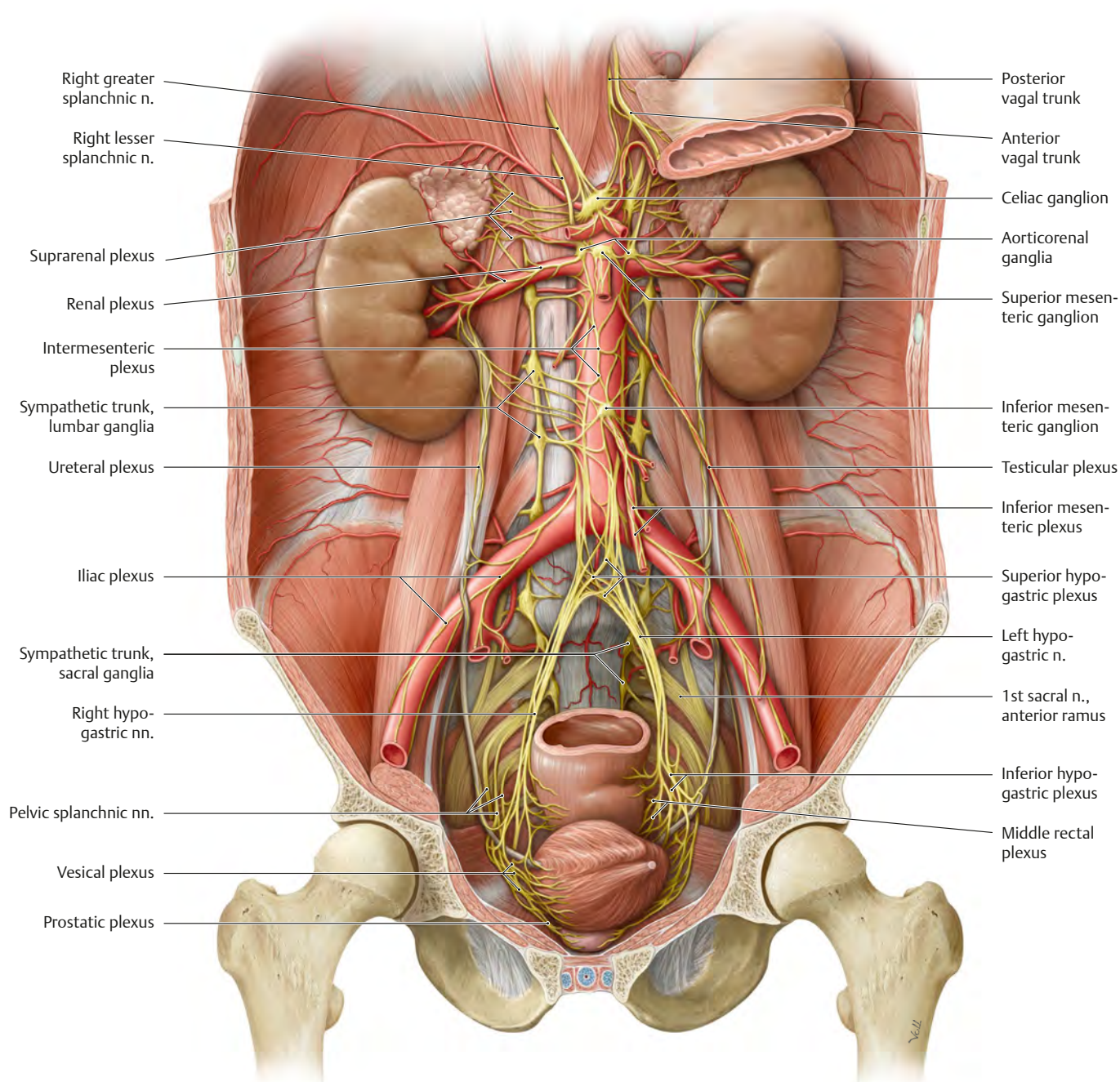


Fig. 16.46 Innervation of the small intestine

Anterior view. *Partially removed:* Stomach, pancreas, and transverse colon (distal part). See p. 215 for schematic.

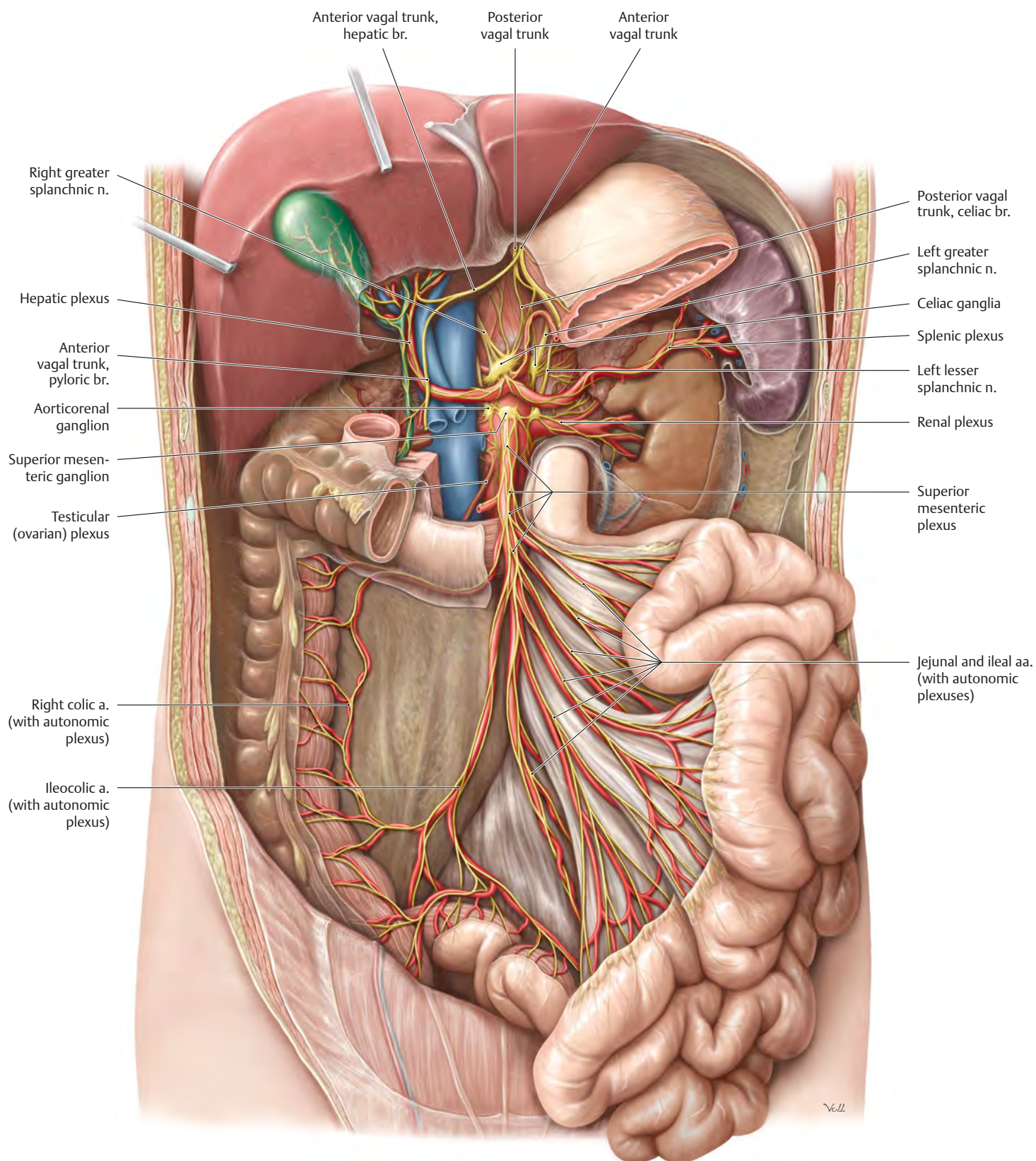
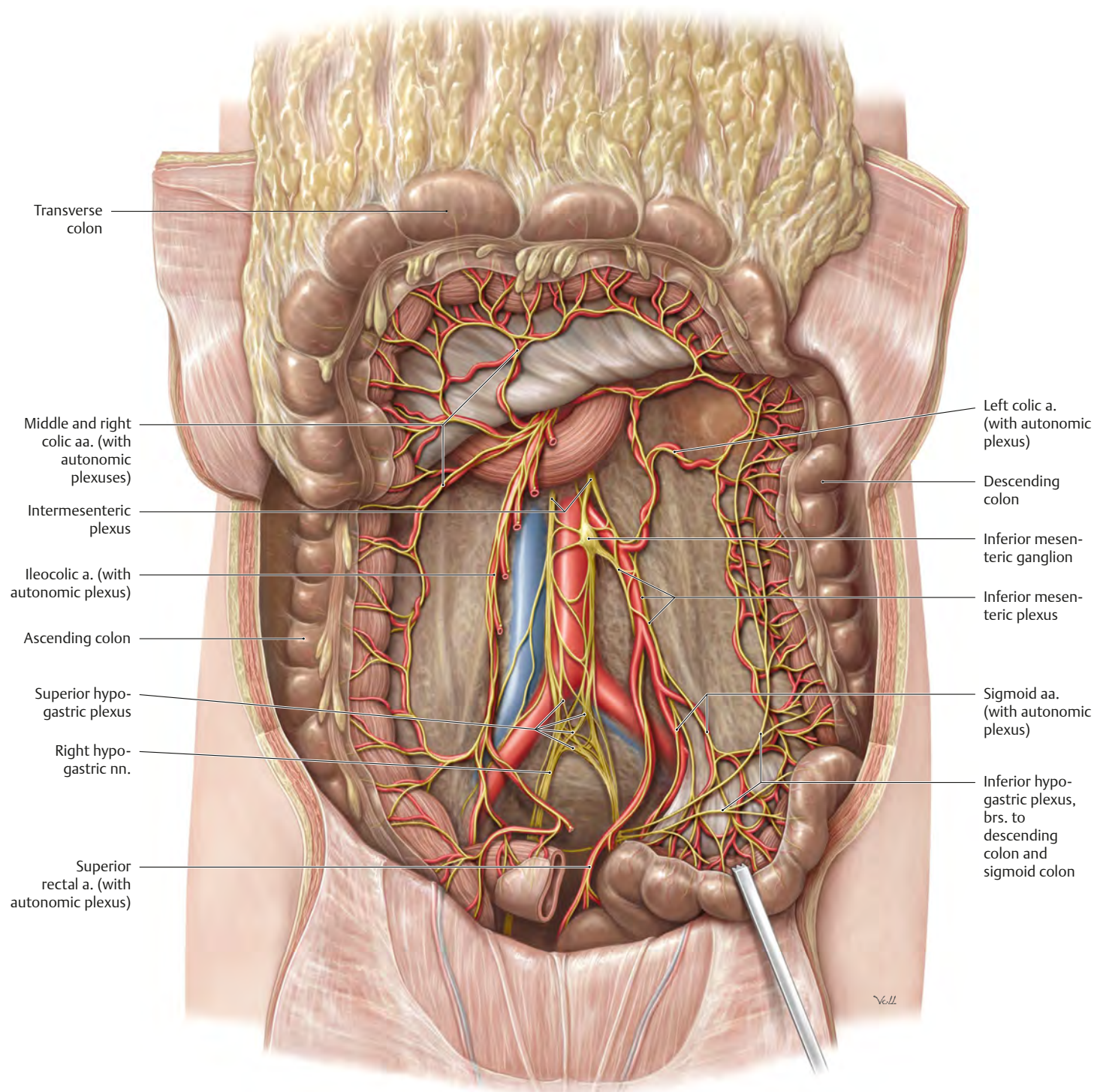
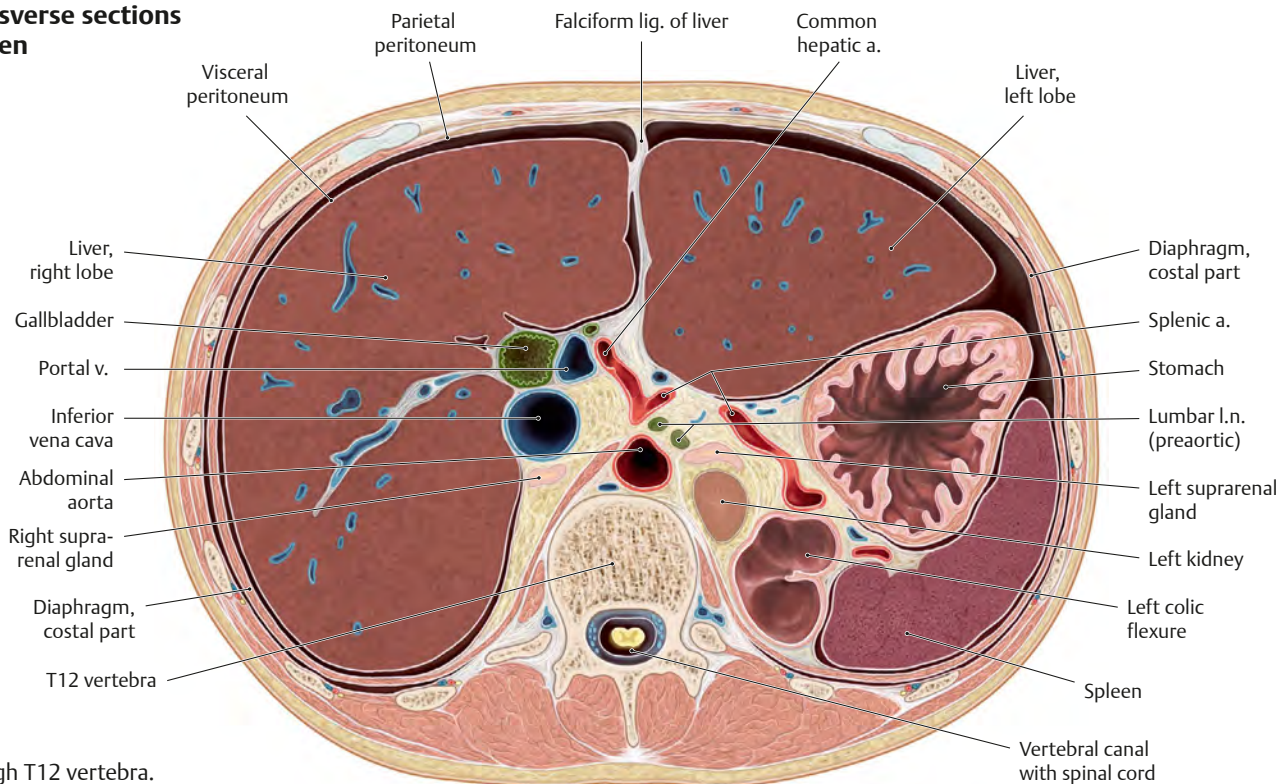
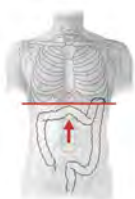


Fig. 16.47 Innervation of the large intestineAnterior view. *Removed:* Small intestine.*Reflected:* Transverse and sigmoid colons. See p. 215 for schematic.

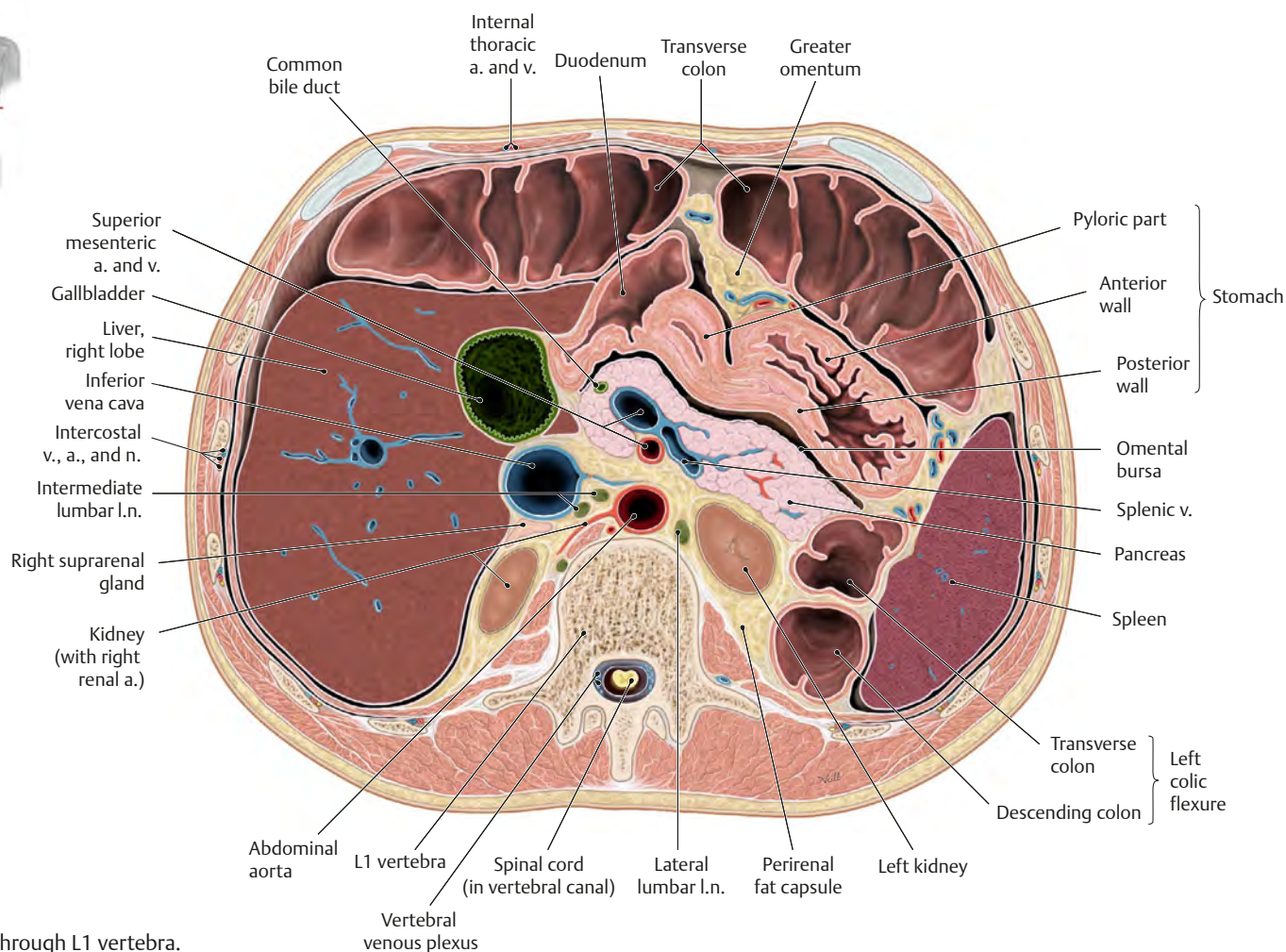
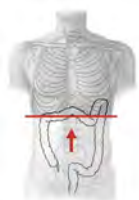
17 Sectional & Radiographic Anatomy

Sectional Anatomy of the Abdomen

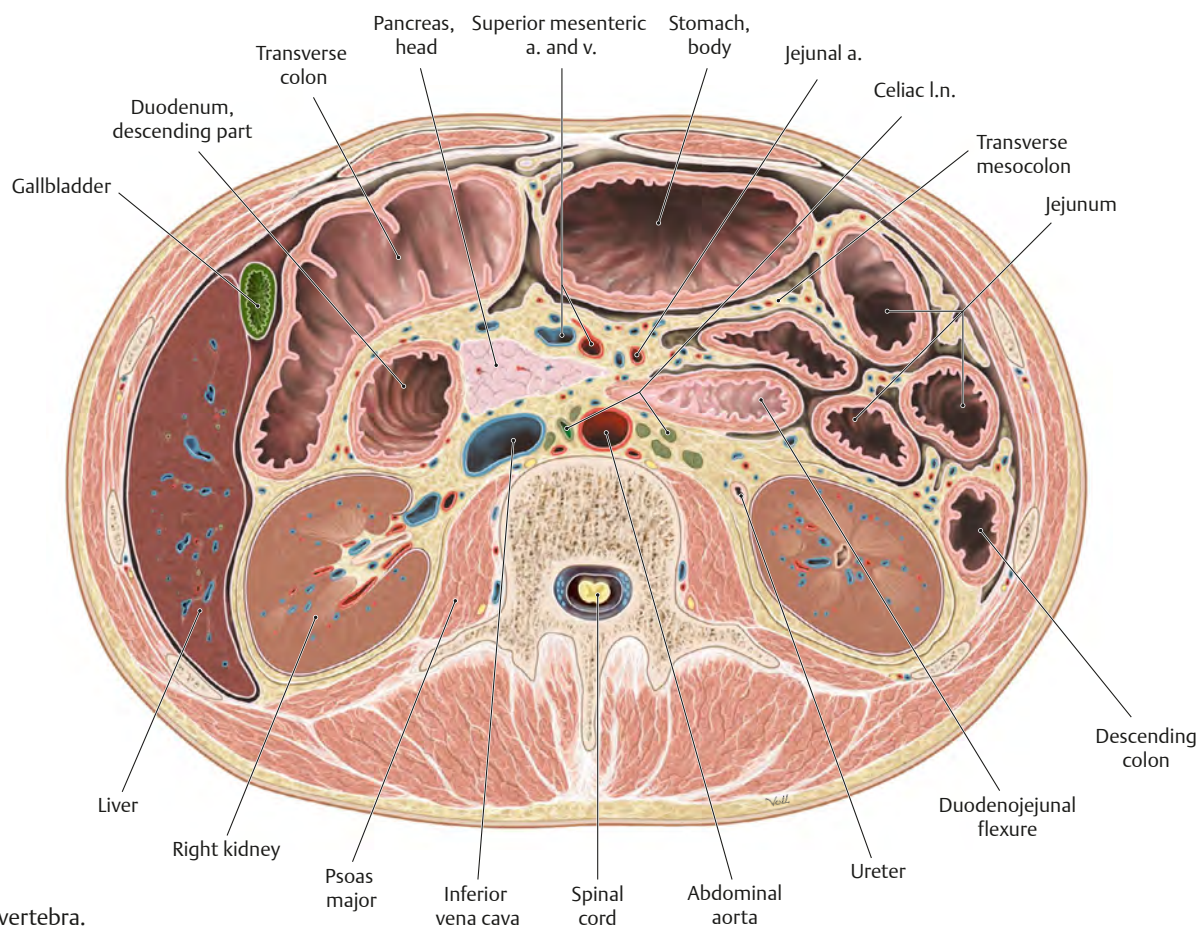
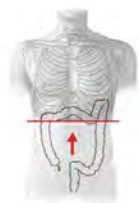
Fig. 17.1 Transverse sections of the abdomen
Inferior view.



A Section through T12 vertebra.



B Section through L1 vertebra.

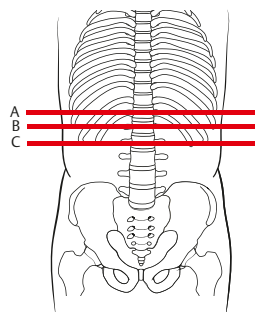


C Section through L2 vertebra.

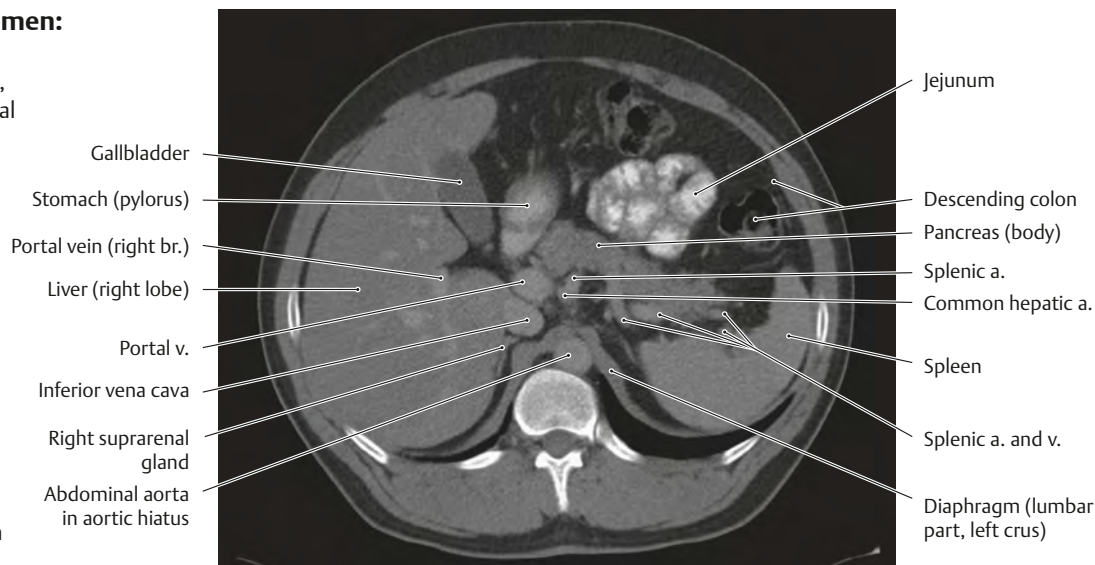
Fig. 17.2 CT of the abdomen:

Transverse sections

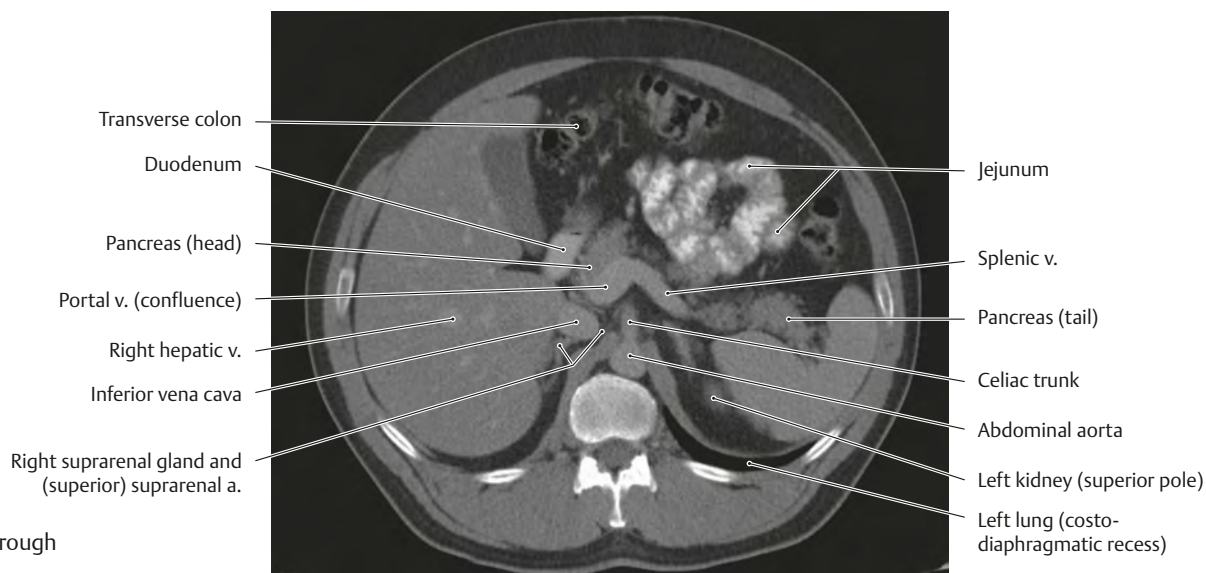
(Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)



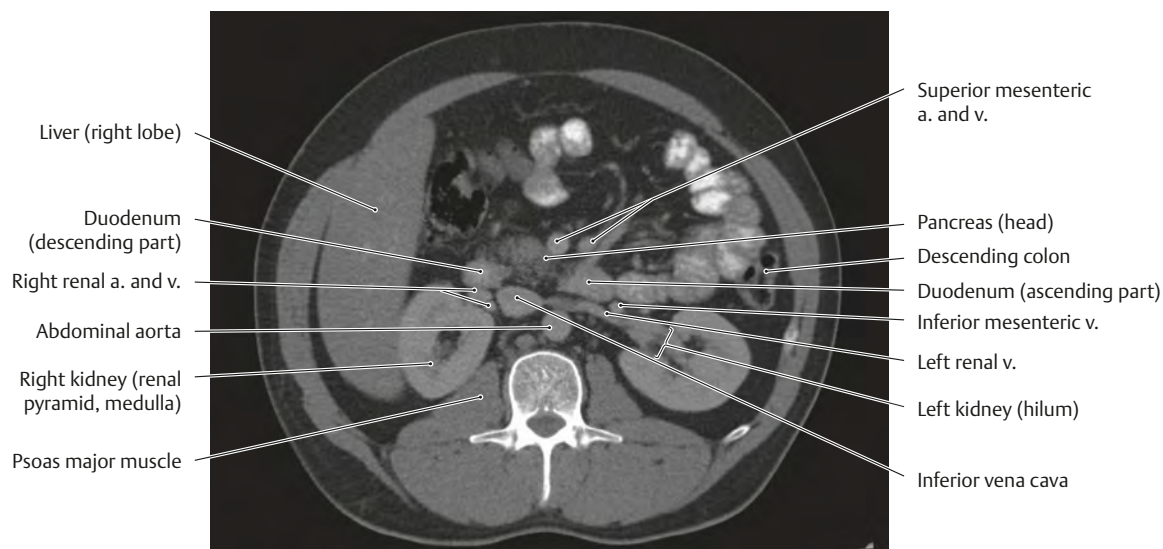
A Transverse section through T12 vertebral level

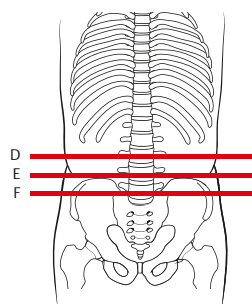


B Transverse section through L1 vertebral level



C Transverse section through L2 vertebral level





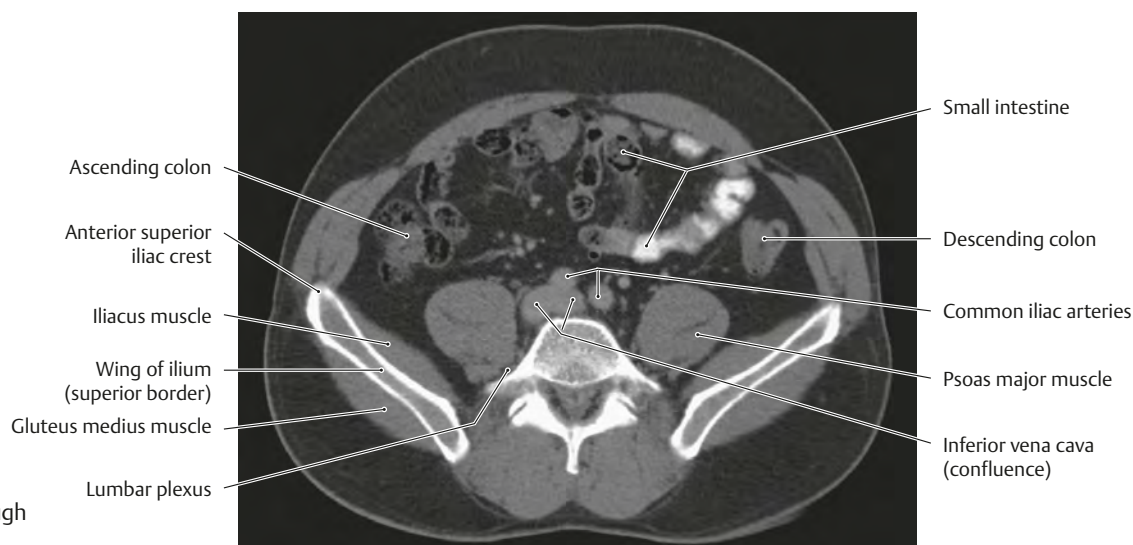
D Transverse section through L3 vertebral level



E Transverse section through L4 vertebral level



F Transverse section through L5 vertebral level



Radiographic Anatomy of the Abdomen (II)

Fig. 17.3 CT of the abdomen:
Sagittal section through the aorta
(Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

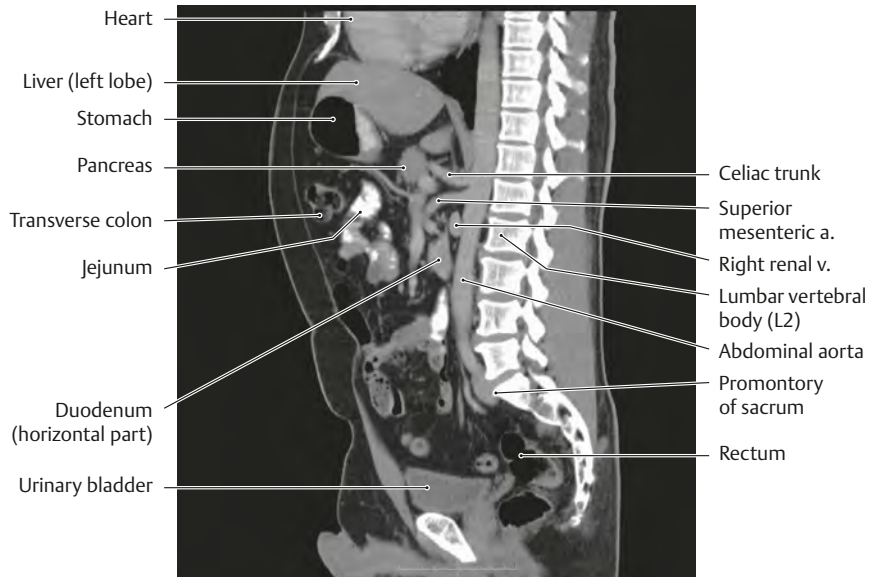
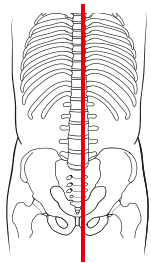


Fig. 17.4 CT of the Abdomen:
Coronal section through the kidneys
(Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

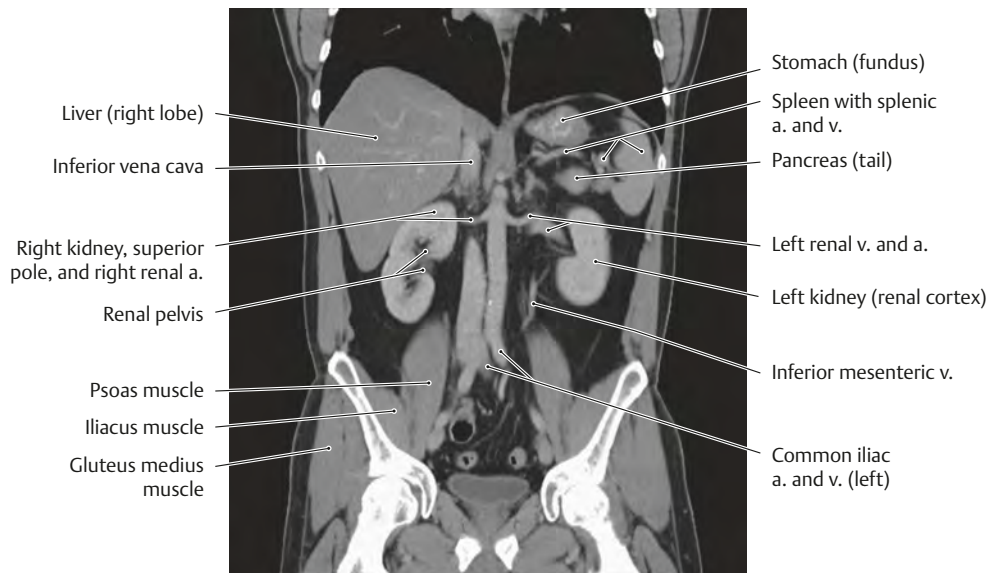
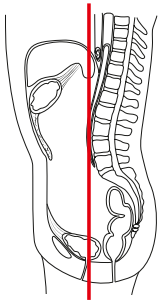


Fig. 17.5 Radiograph of intravenous
pylegram
Anterior view.

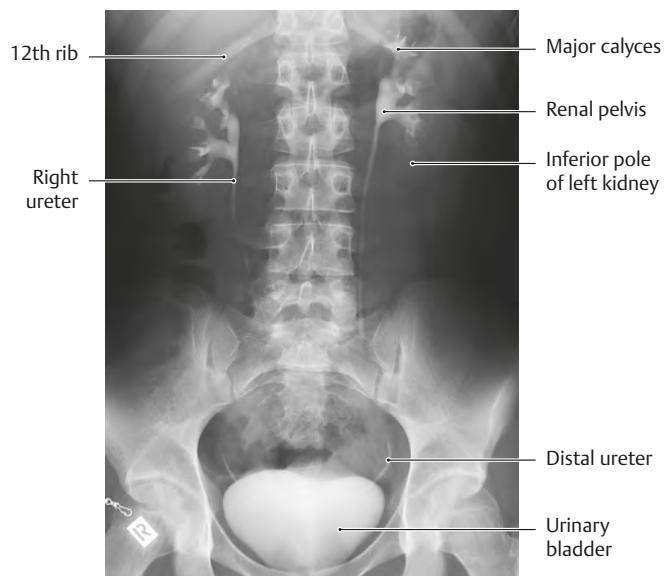
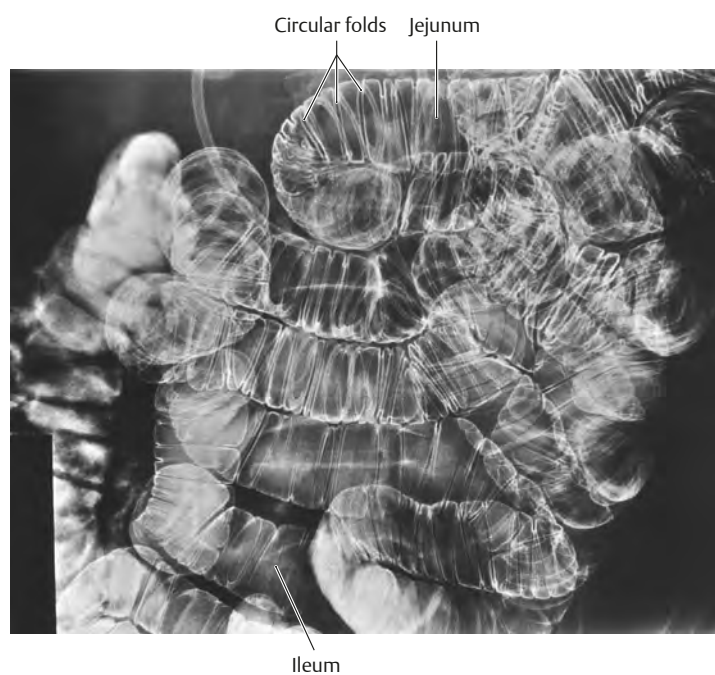
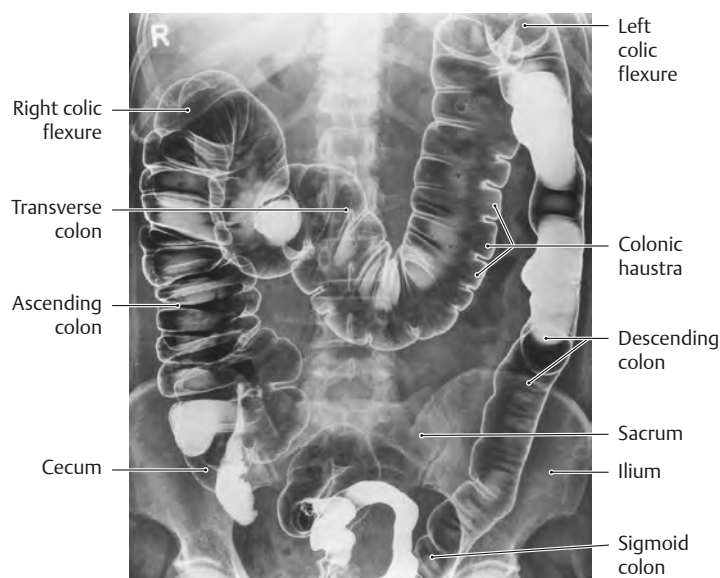


Fig. 17.6 Radiographs of double contrast barium enema.

Anterior view.



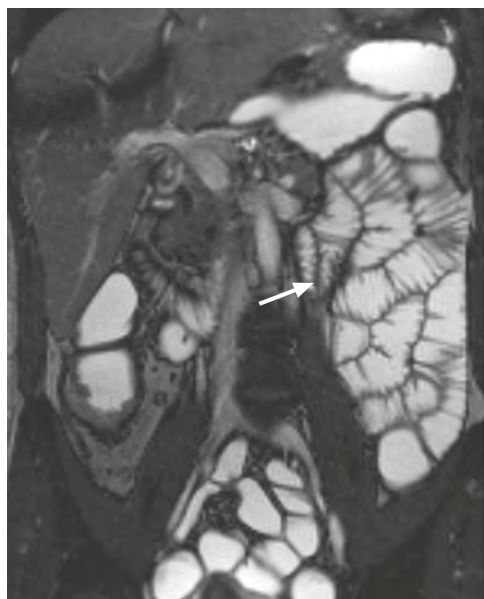
A Small intestine. (Reproduced courtesy of Universitätsmedizin Mainz, Klinik und Poliklinik für Diagnostische und Interventionelle Radiologie.)



B Large intestine. (Reproduced courtesy of Klinik für Diagnostische Radiologie, Universitätsklinikum Schleswig Holstein, Campus Kiel: Prof. Dr. Med. S. Müller-Huelsbeck.)

Fig. 17.7 MRI of the intestines

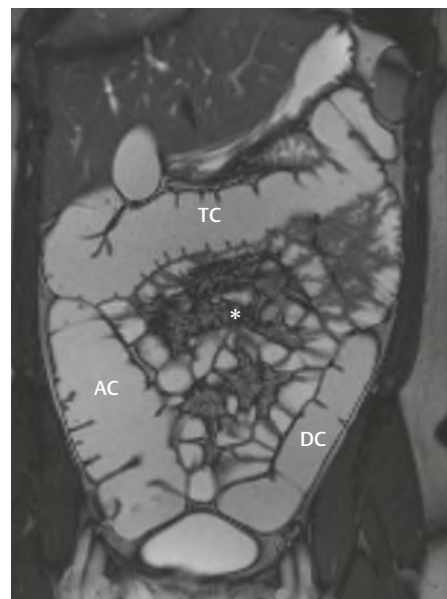
Coronal view. Sectional imaging modalities like CT and MR have mostly replaced conventional radiographs in the evaluation of gastrointestinal disease. (Reproduced from Krombach GA, Mahnken AH. Body Imaging: Thorax and Abdomen. New York, NY: Thieme; 2018.)



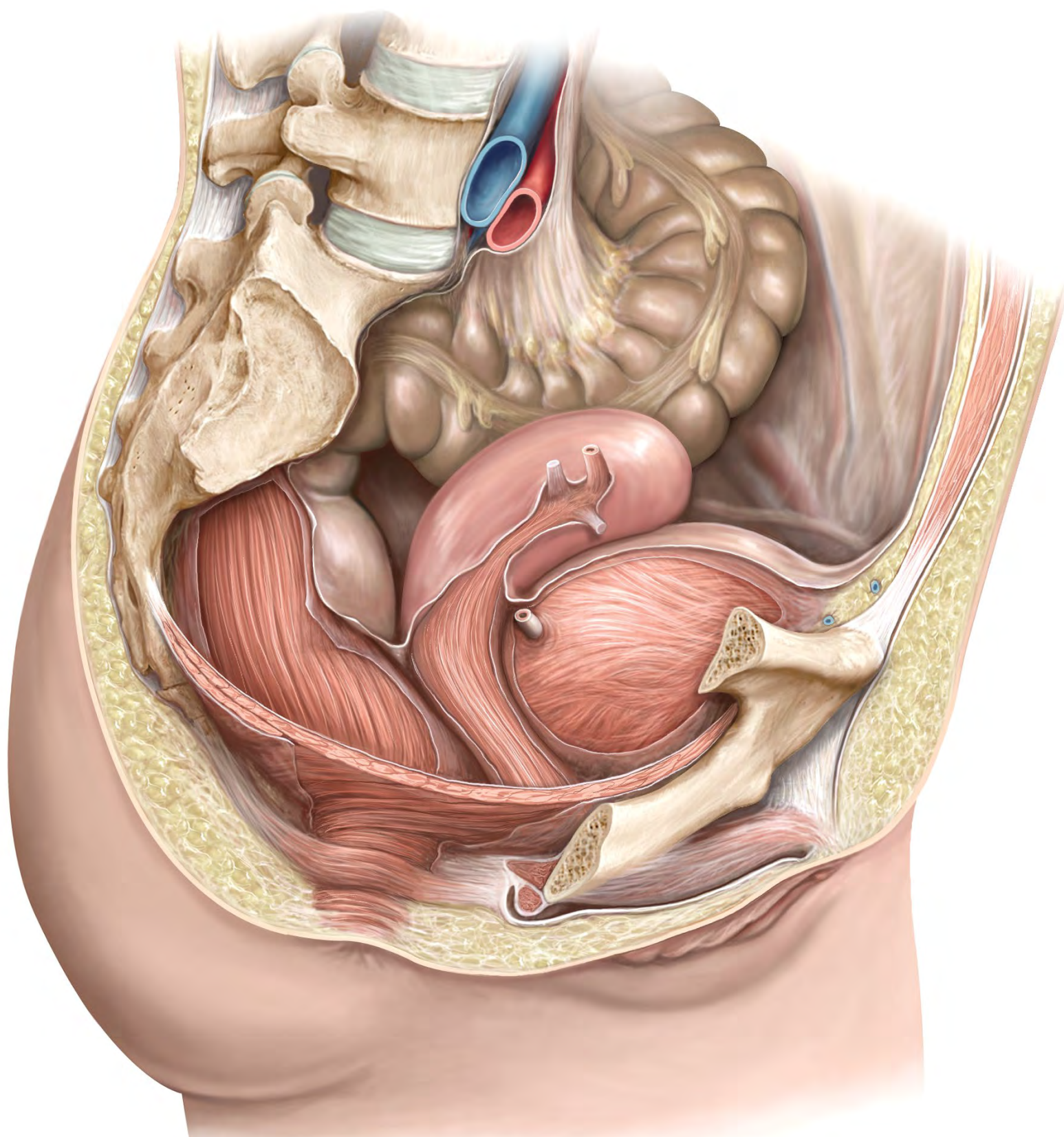
A Jejunum (arrow)



B Ileum (arrow), transverse colon (TC), urinary bladder (B)



C Ascending colon (AC), descending colon (DC), transverse colon (TC), * small bowel and mesenteric structures.



Pelvis & Perineum

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23 Sectional & Radiographic Anatomy

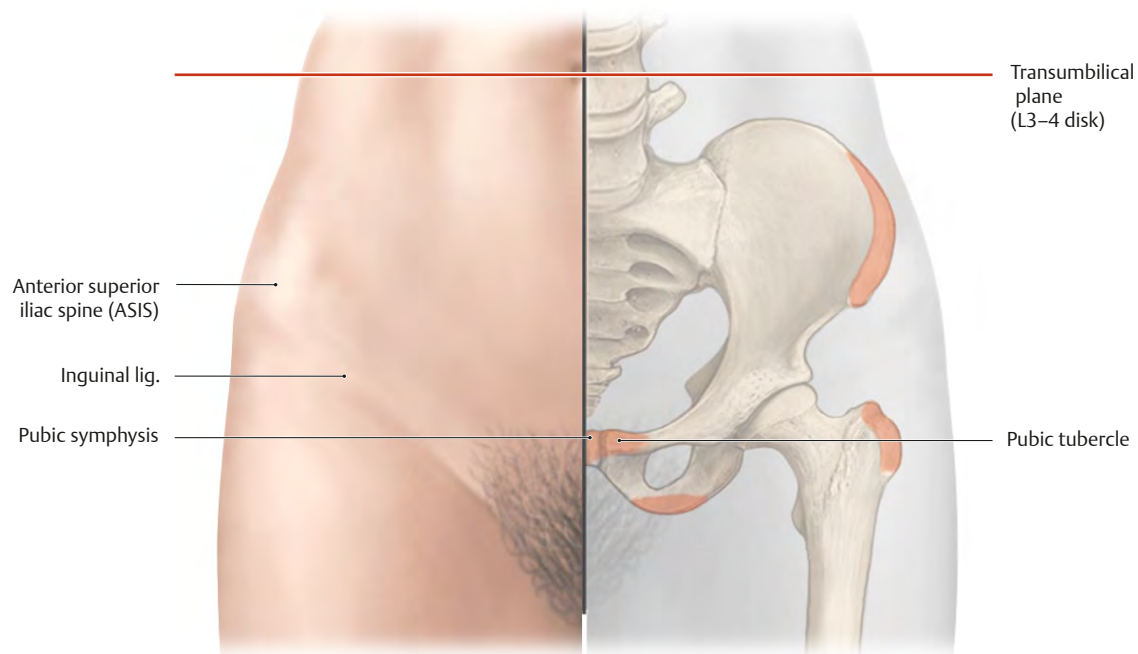
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18 Surface Anatomy

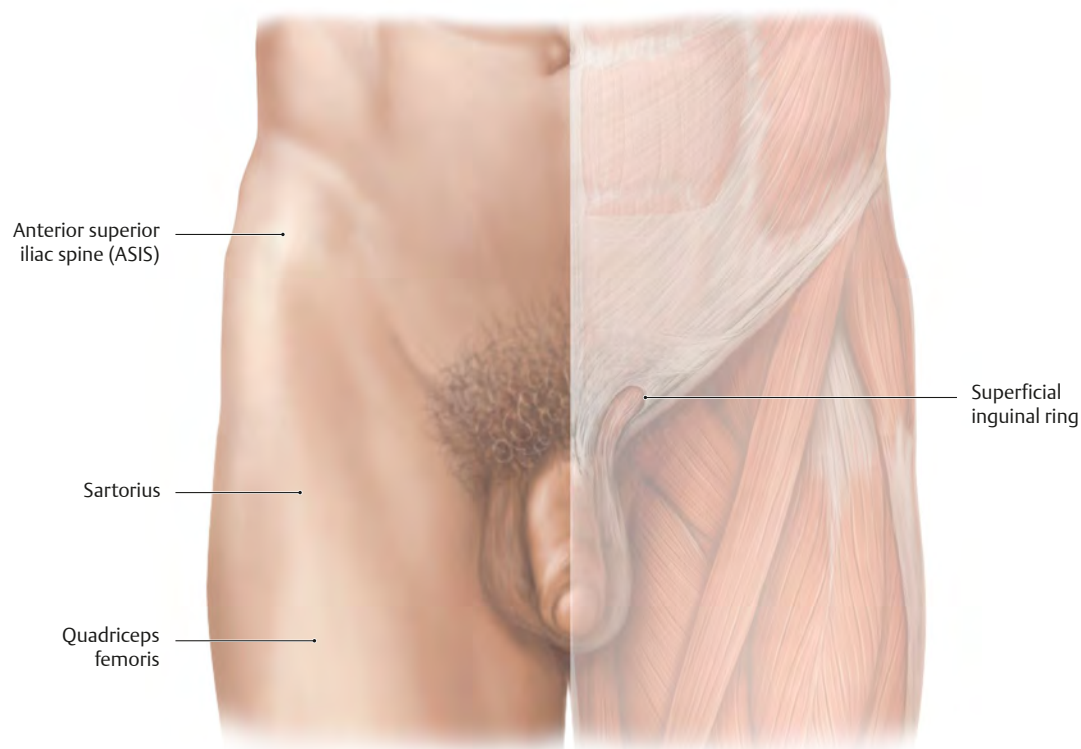
Surface Anatomy

Fig. 18.1 Palpable structures of the pelvis

Anterior view. The structures are common to both male and female. See pp. 2–3 for structures of the back.



A Bony prominences, female pelvis.



B Musculature, male pelvis.

The *perineum* is the inferiormost portion of the trunk, between the thighs and buttocks, extending from the pubis to the coccyx and superiorly to the inferior fascia of the pelvic diaphragm, including all

of the structures of the anal and urogenital triangles (**Fig. 18.2A**). The bilateral boundaries of the perineum are the pubic symphysis, ischio-pubic ramus, ischial tuberosity, sacrotuberous ligament, and coccyx.

Fig. 18.2 Regions of the female perineum

Lithotomy position.

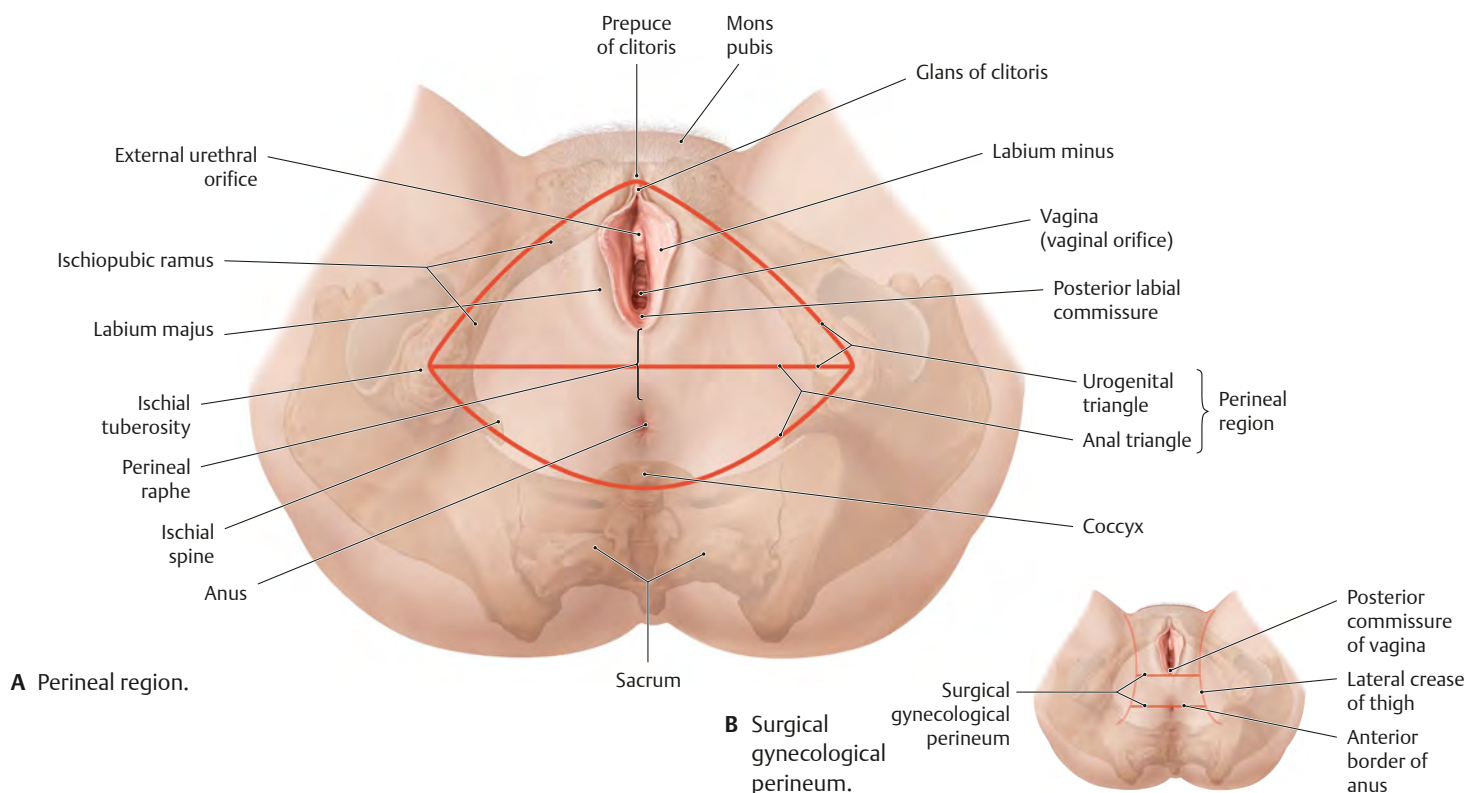
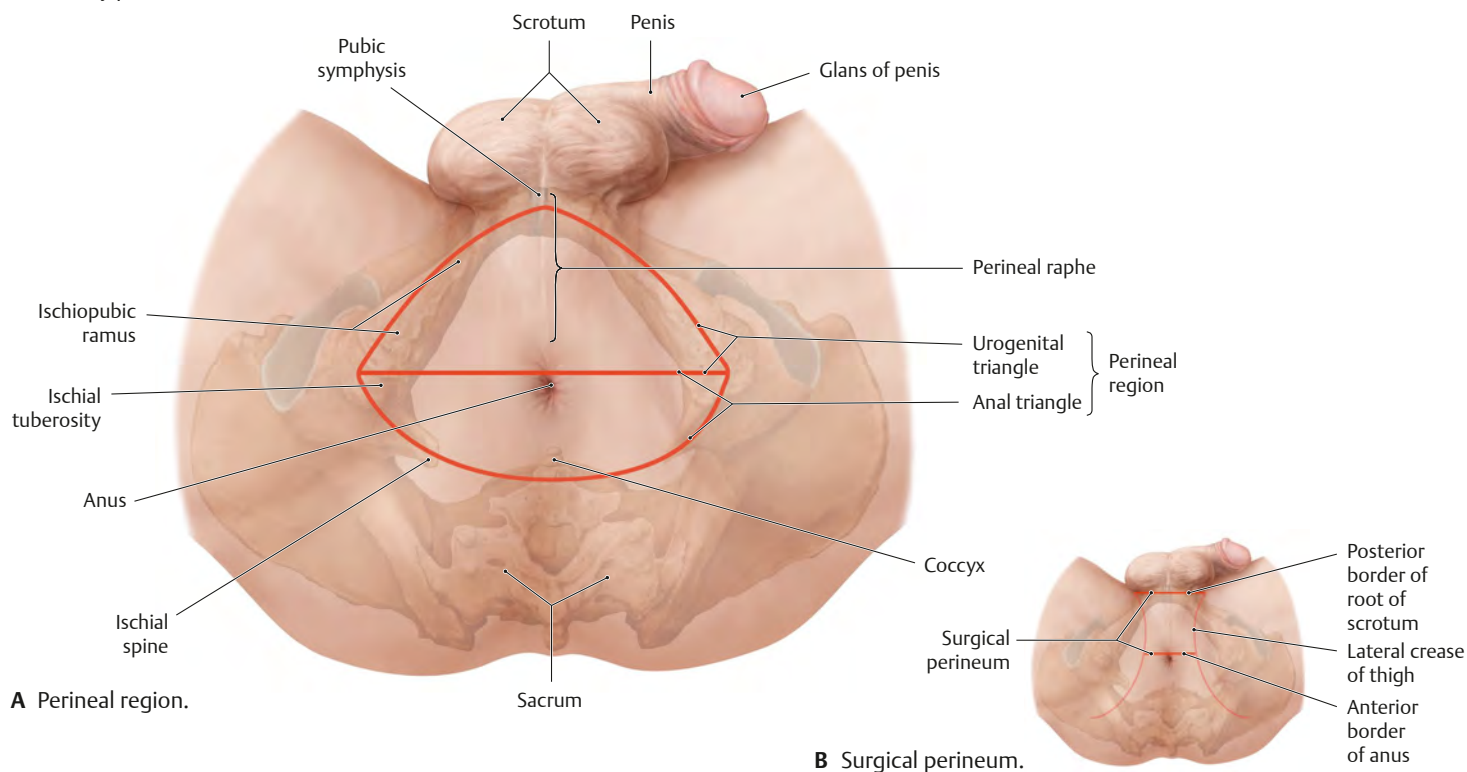


Fig. 18.3 Regions of the male perineum

Lithotomy position.



19 Bones, Ligaments & Muscles

Pelvic Girdle

The pelvis is the region of the body inferior to the abdomen and surrounded by the pelvic girdle, which is the two coxal (hip) bones and the sacrum that connect the vertebral column to the femur. The two coxal bones are connected to each other at the cartilaginous pubic

symphysis and to the sacrum via the sacroiliac joints, creating the pelvic brim (red, **Fig. 19.1**). The stability of the pelvic girdle is necessary for the transfer of trunk loads to the lower limb, which occurs in normal gait.

Fig. 19.1 Pelvic girdle
Anterosuperior view. The pelvic girdle consists of the two coxal bones and the sacrum.

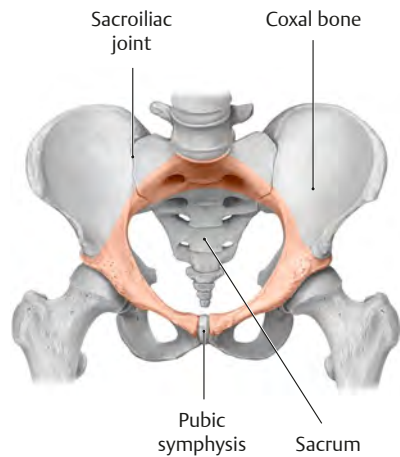
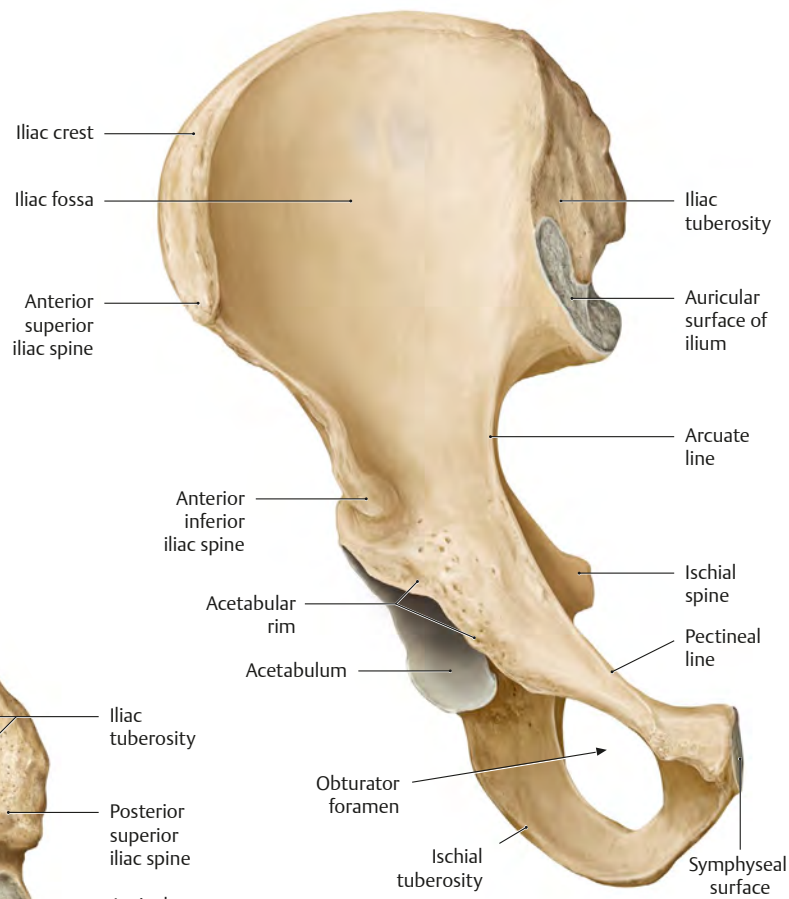


Fig. 19.2 Coxal bone
Right side (male).

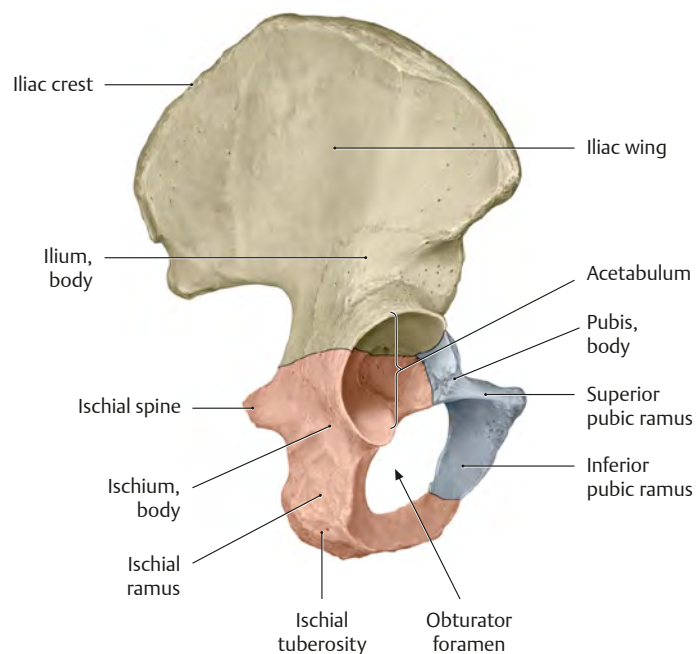


A Anterior view.

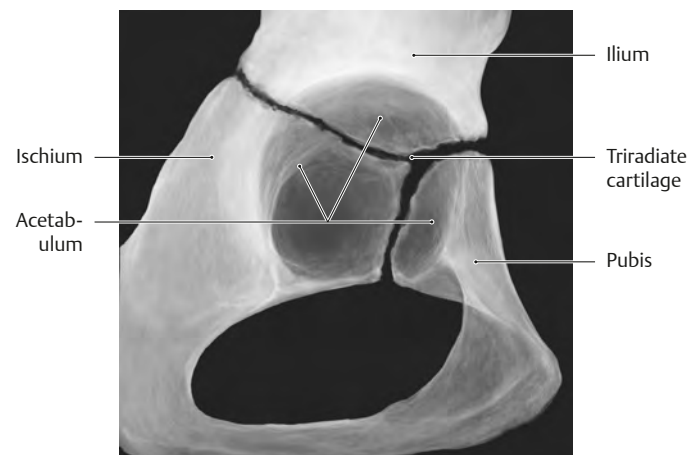
B Medial view.

Fig. 19.3 Triradiate cartilage of the coxal bone

Right coxal bone, lateral view. The coxal bone consists of the ilium, ischium, and pubis.



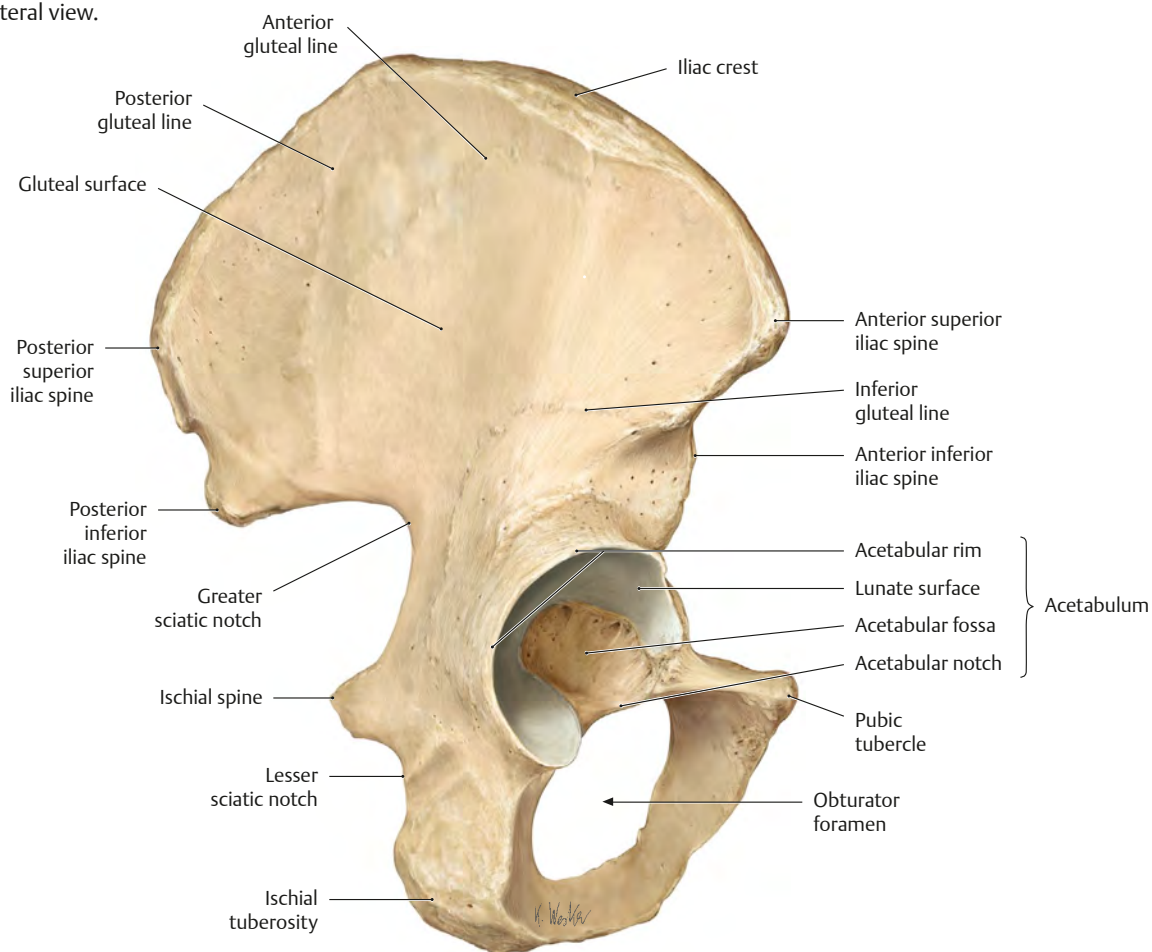
A Junction of the triradiate cartilage.



B Radiograph of a child's acetabulum.

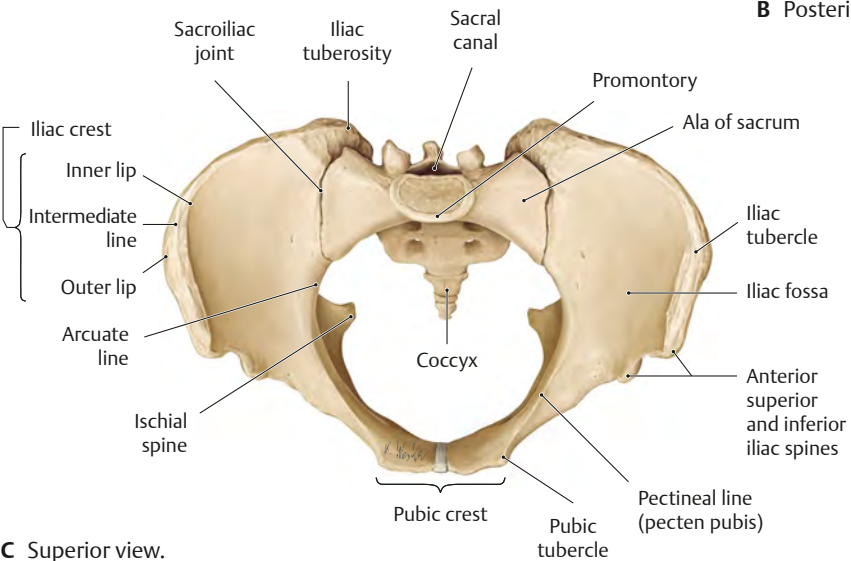
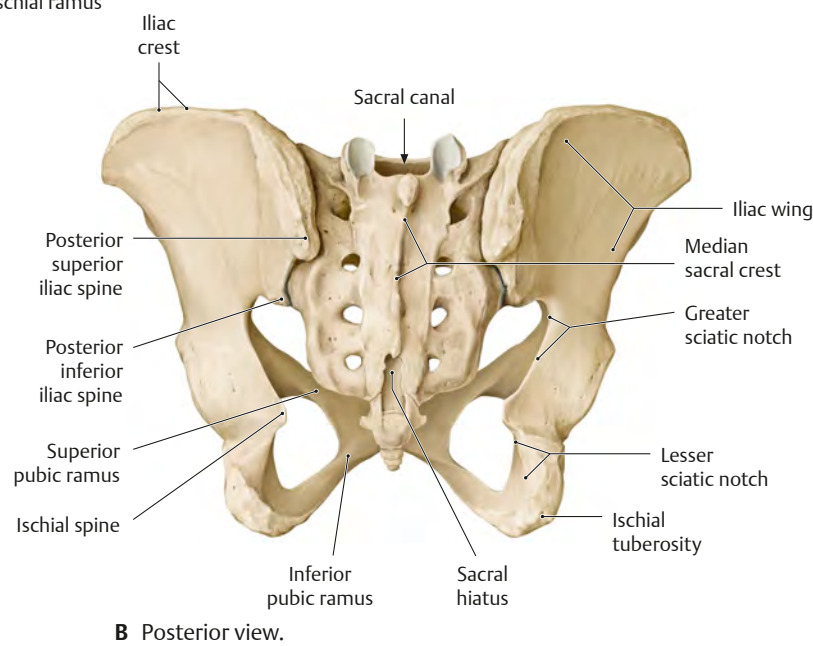
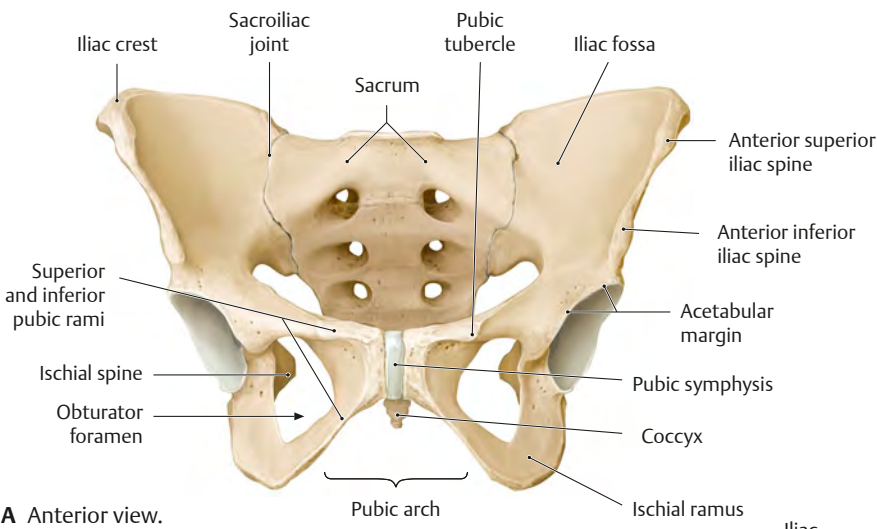
Fig. 19.4 Coxal bone

Right side (male), lateral view.



Female & Male Pelvis

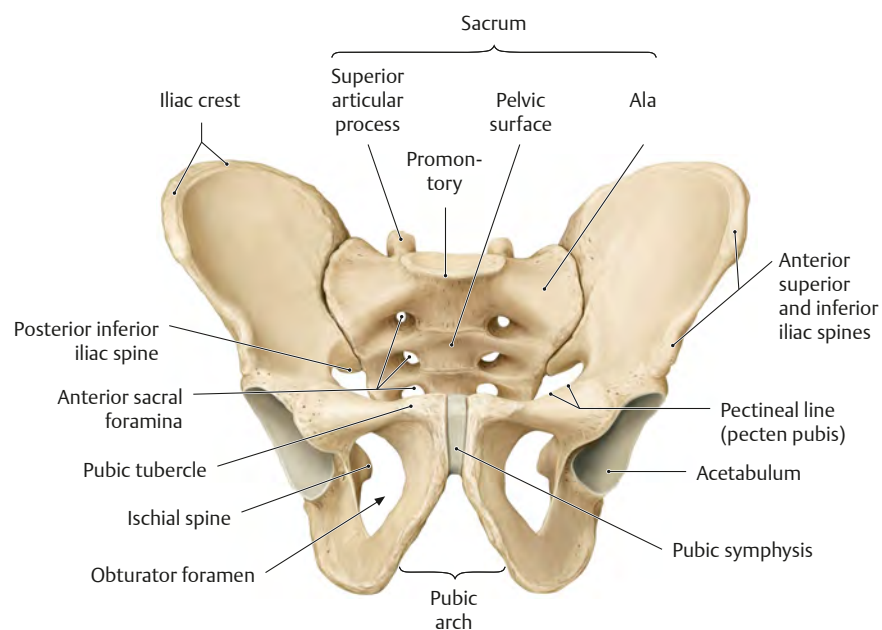
Fig. 19.5 Female pelvis



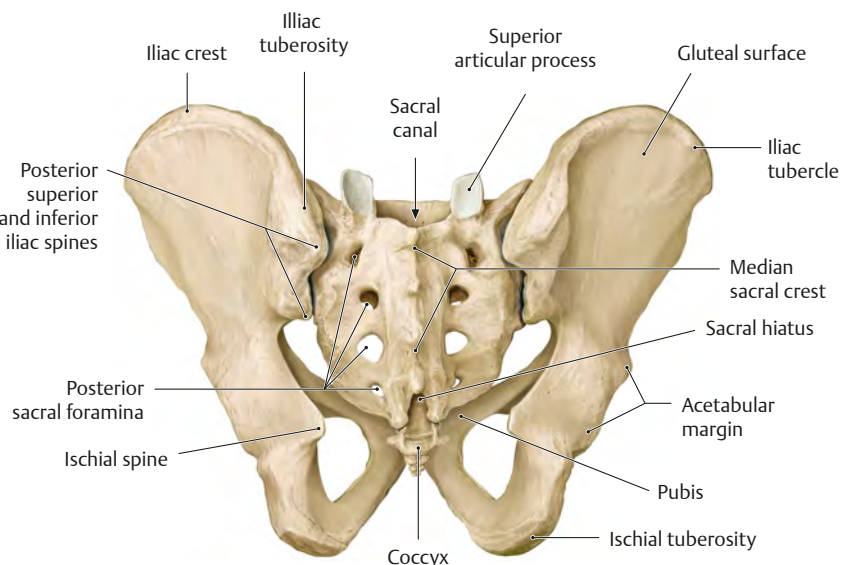
 **Clinical box 19.1**

Childbirth
A non-optimal relation between the maternal pelvis and the fetal head may lead to complications during childbirth, potentially necessitating a caesarean section. Maternal causes include earlier pelvic trauma and innate malformations. Fetal causes include hydrocephalus (disturbed circulation of cerebrospinal fluid, leading to brain dilation and cranial expansion).

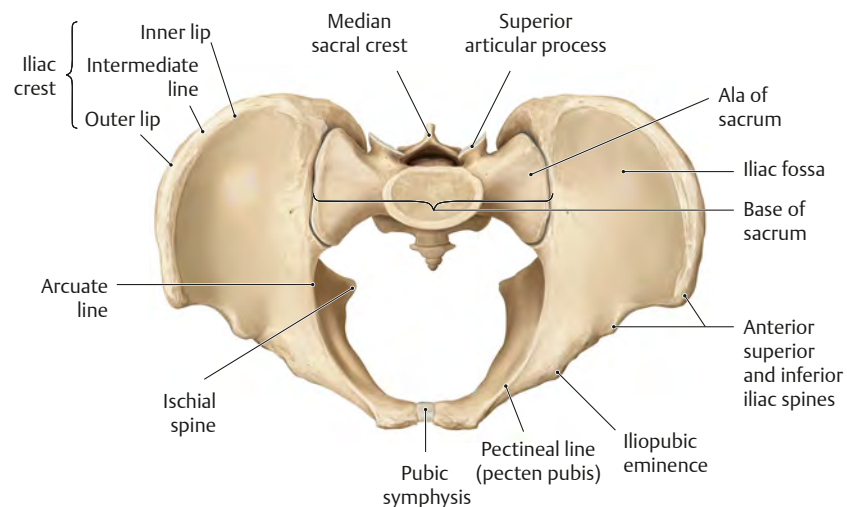
Fig. 19.6 Male pelvis



A Anterior view.



B Posterior view.



C Superior view.

Female & Male Pelvic Measurements

The *pelvic inlet*, the superior aperture of the pelvis, is the boundary between the abdominal and pelvic cavities. It is defined by the plane that passes through its edge, the *pelvic brim*, which is the prominence of the sacrum, the arcuate and pectineal lines, and the upper margin of the pubic symphysis. Occasionally, the terms *pelvic inlet* and *pelvic brim* are used interchangeably. The *pelvic outlet* is the plane of the inferior aperture, passing through the pubic arch, the ischial tuberosities, the inferior margin of the sacrotuberous ligament, and the tip of the coccyx.

Table 19.1	Gender-specific features of the pelvis	
Structure	♀	♂
False pelvis	Wide and shallow	Narrow and deep
Pelvic inlet	Transversely oval	Heart-shaped
Pelvic outlet	Roomy and round	Narrow and oblong
Ischial tuberosities	Everted	Inverted
Pelvic cavity	Roomy and shallow	Narrow and deep
Sacrum	Short, wide, and flat	Long, narrow, and convex
Subpubic angle	90–100 degrees	70 degrees

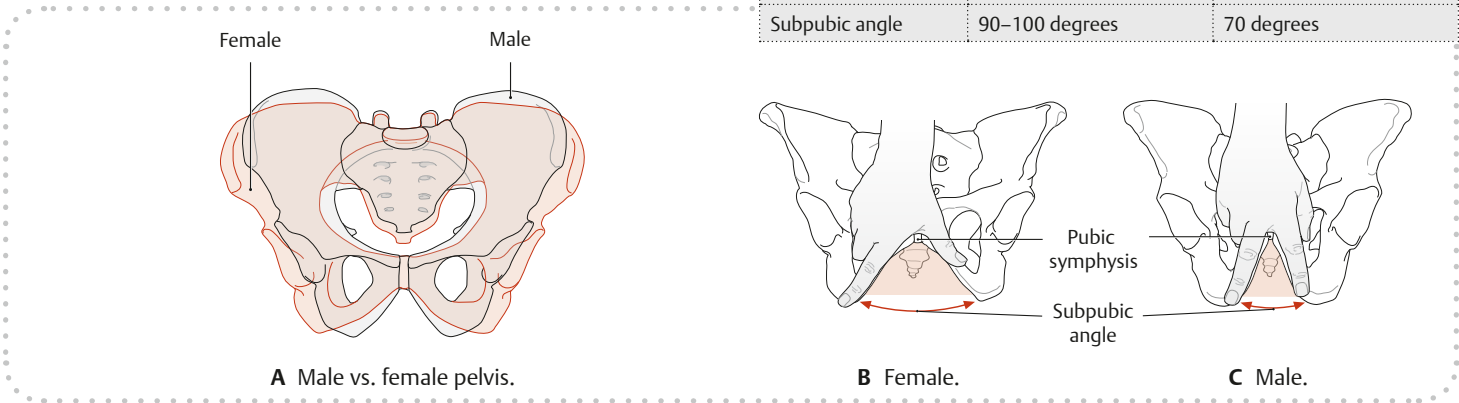
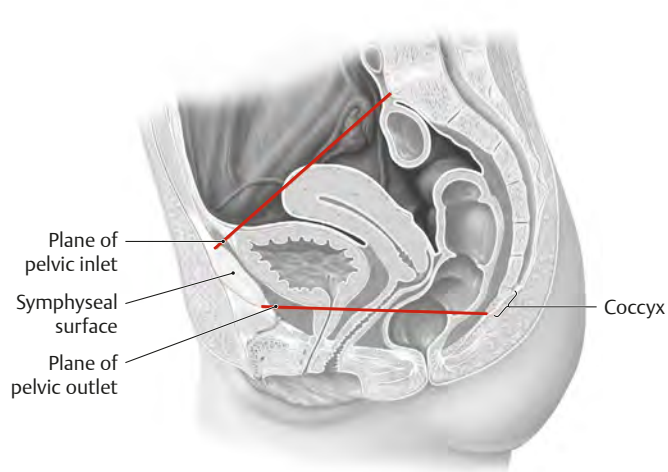
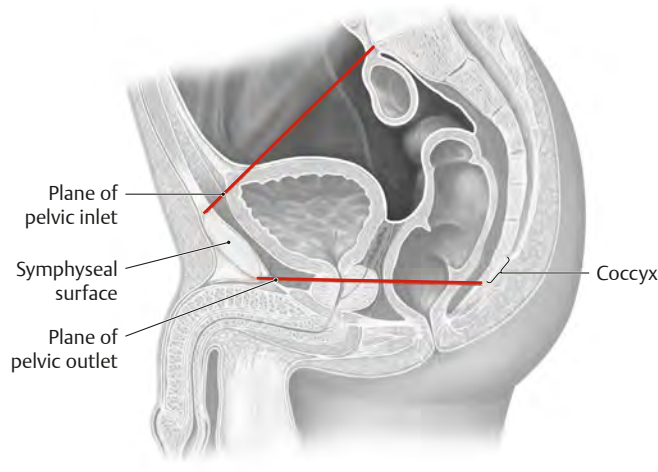


Fig. 19.7 True and false pelvis

The pelvis is the region of the body inferior to the abdomen, surrounded by the pelvic girdle. The *false pelvis* is immediately inferior to the abdominal cavity, between the iliac alae, and superior to the pelvic inlet. The *true pelvis* is the bony-walled space between the pelvic inlet and the pelvic outlet. It is bounded inferiorly by the pelvic diaphragm, also called the pelvic floor.



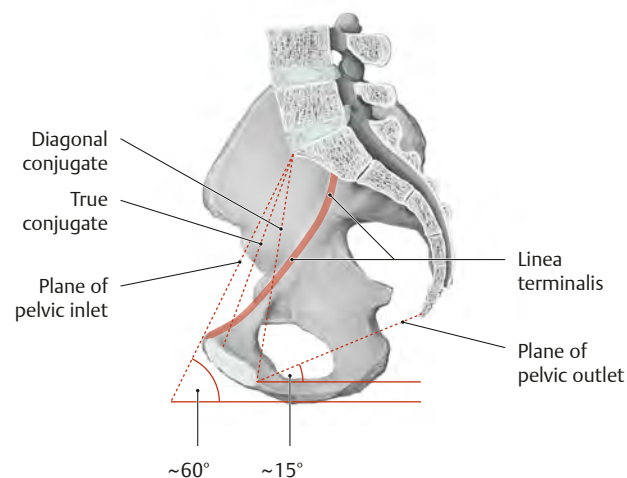
A Female. Midsagittal section, viewed from left side.



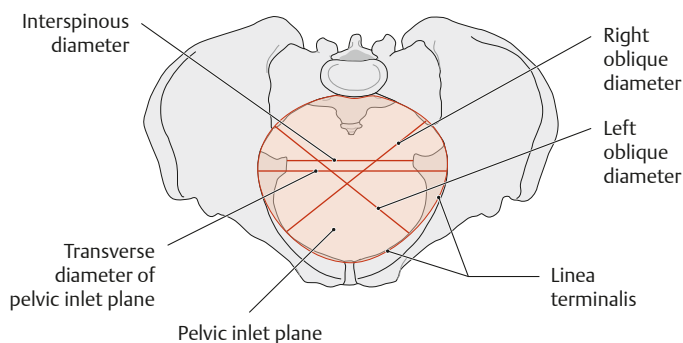
B Male. Midsagittal section, viewed from left side.

Fig. 19.8 Narrowest diameter of female pelvic canal

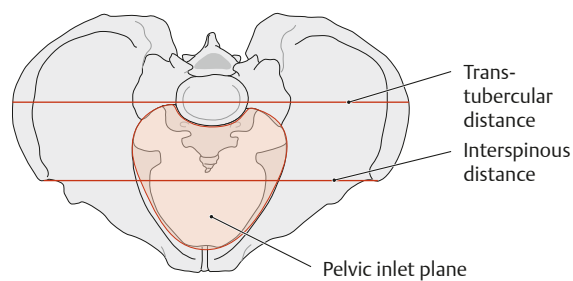
The true conjugate, the distance between the promontory and the most posterosuperior point of the pubic symphysis, is the narrowest AP (anteroposterior) diameter of the pelvic (birth) canal. This diameter is difficult to measure due to the viscera, so the diagonal conjugate, the distance between the promontory and the inferior border of the pubic symphysis, is used to estimate it. The linea terminalis is part of the border defining the pelvic inlet (pelvic brim).

**Fig. 19.9 Pelvic inlet and outlet**

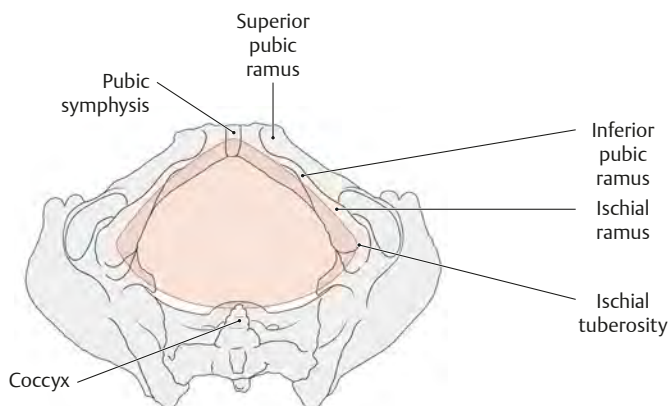
The measurements shown are applicable to both male and female. The transverse and oblique diameters of the female pelvic inlet are obstetrically important, as they are the measure of the diameter of the pelvic (birth) canal. The interspinous distance is the narrowest diameter of the pelvic outlet.



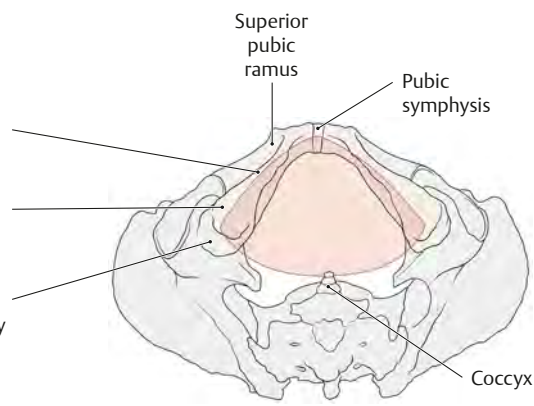
A Female pelvis, superior view.
Pelvic inlet outlined in red.



B Male pelvis, superior view.
Pelvic inlet outlined in red.



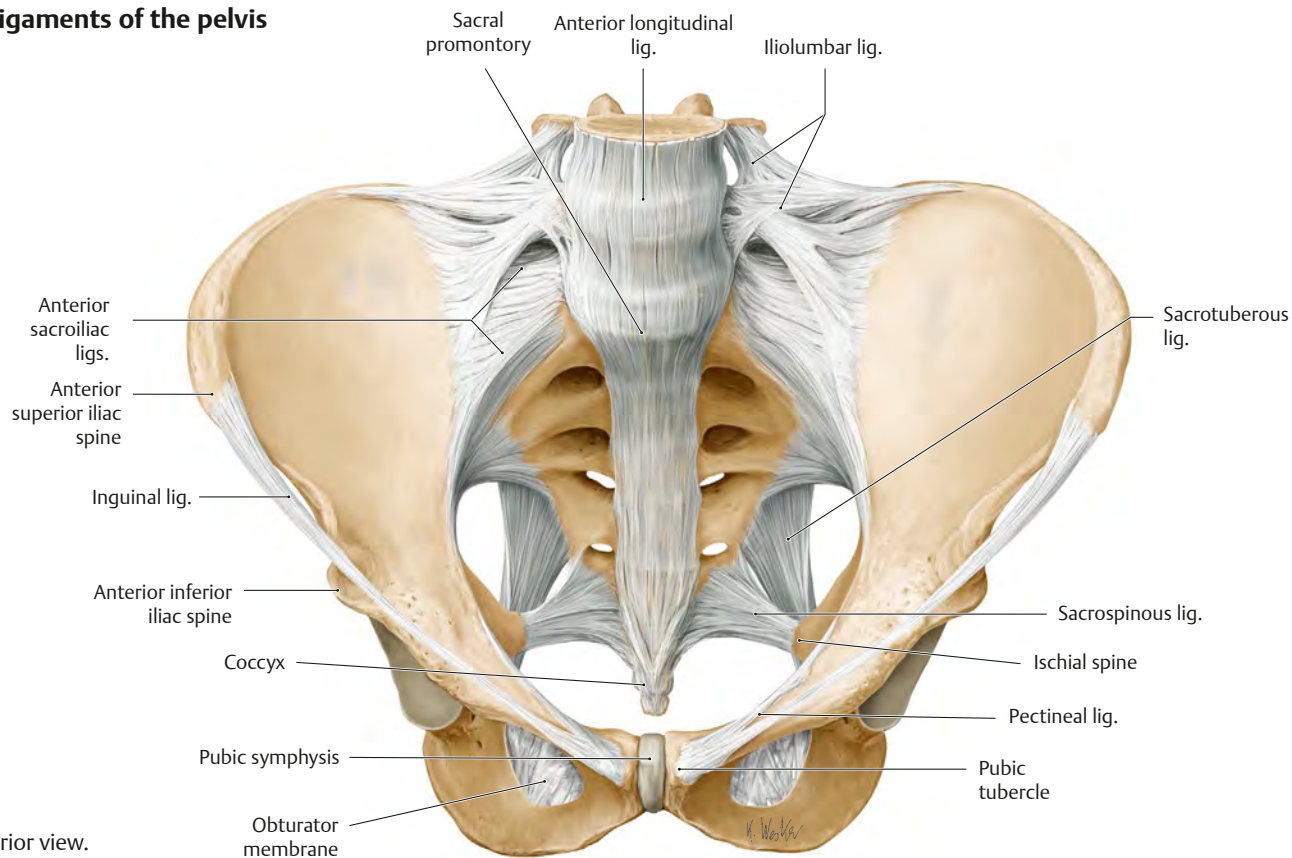
C Female pelvis, inferior view.
Pelvic outlet outlined in red.



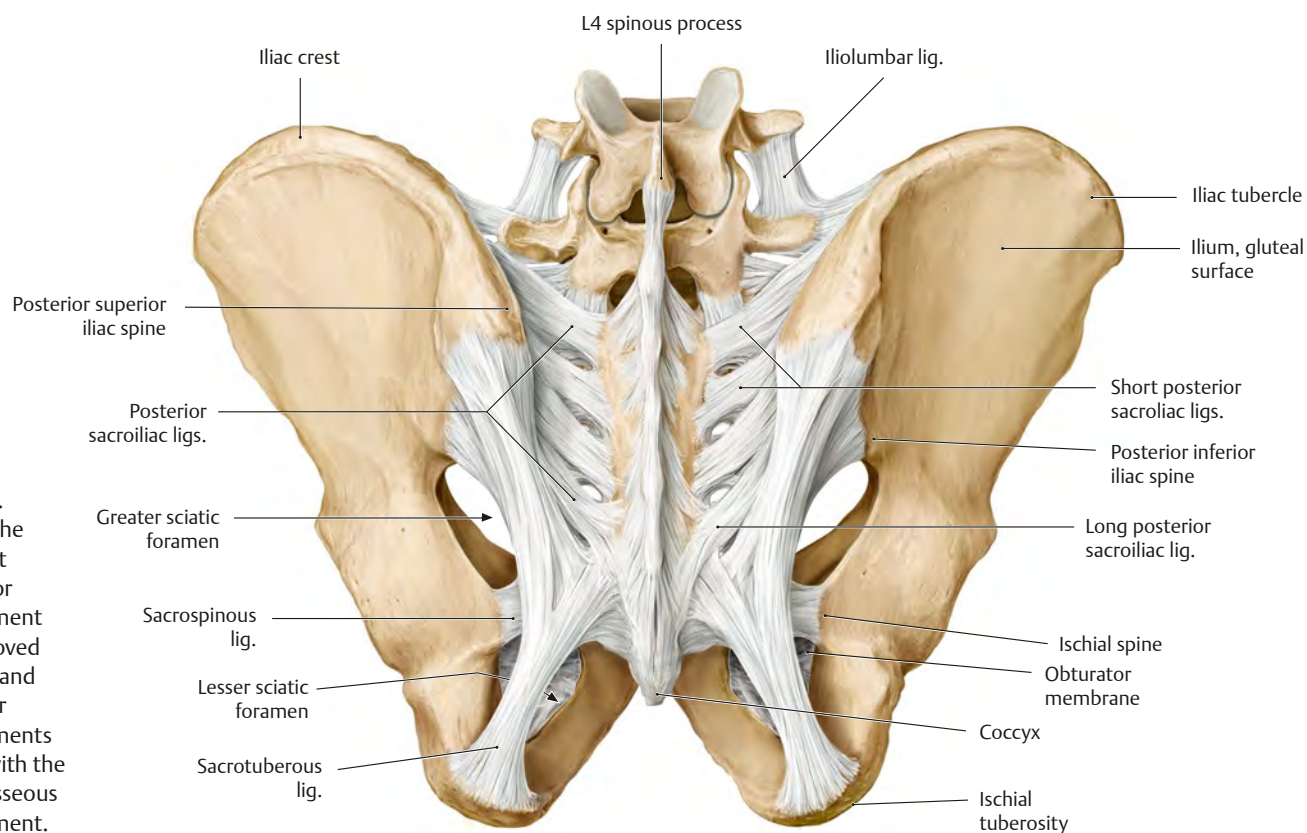
D Male pelvis, inferior view.
Pelvic outlet outlined in red.

Pelvic Ligaments

Fig. 19.10 Ligaments of the pelvis
Male pelvis.



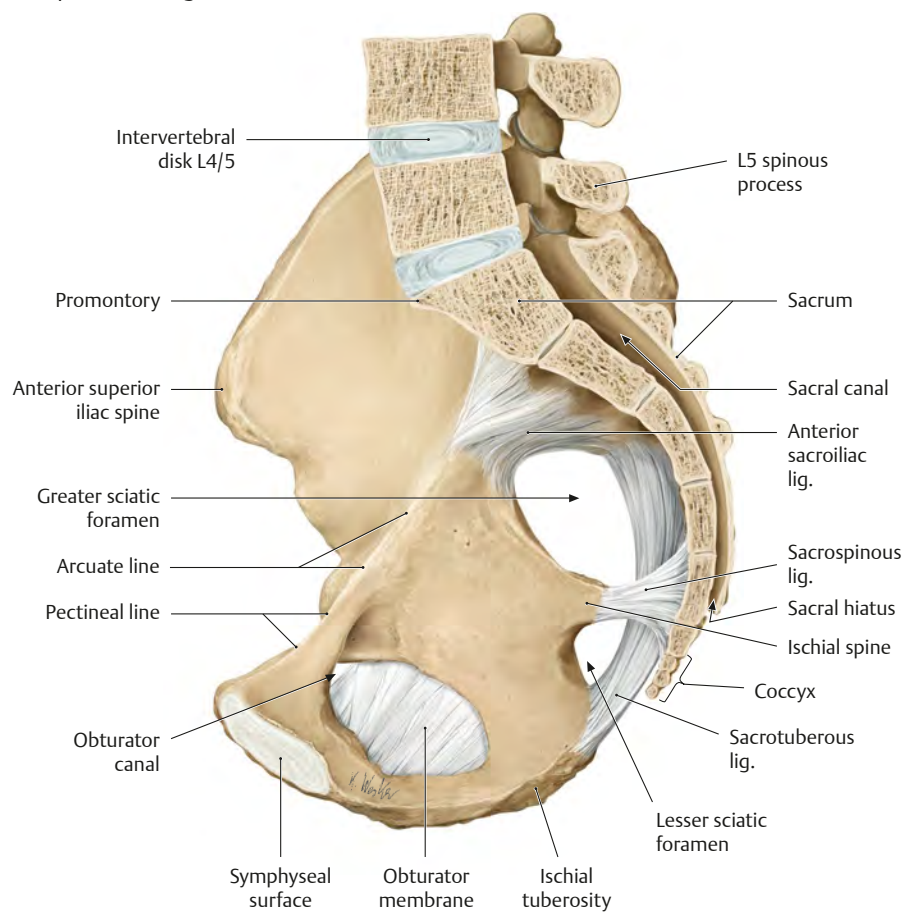
A Anterosuperior view.



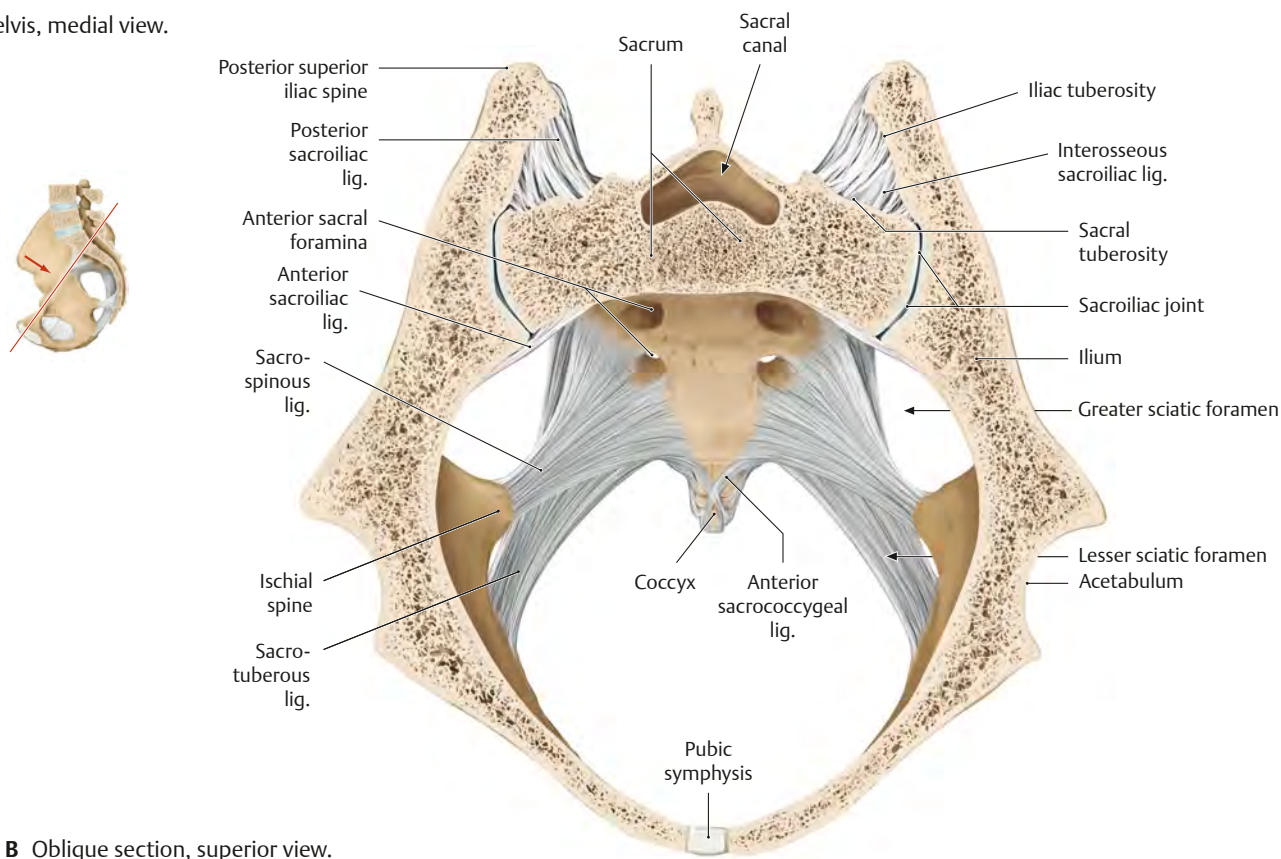
B Posterior view.
On the right, the superficial part of the posterior sacroiliac ligament has been removed to reveal long and short posterior sacroiliac ligaments which blend with the deeper interosseous sacroiliac ligament.

Fig. 19.11 Ligaments of the sacroiliac joint

Male pelvis, midsagittal section.



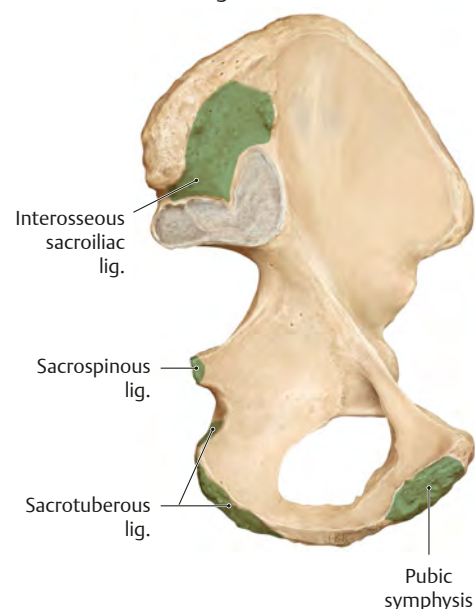
A Right half of pelvis, medial view.



B Oblique section, superior view.

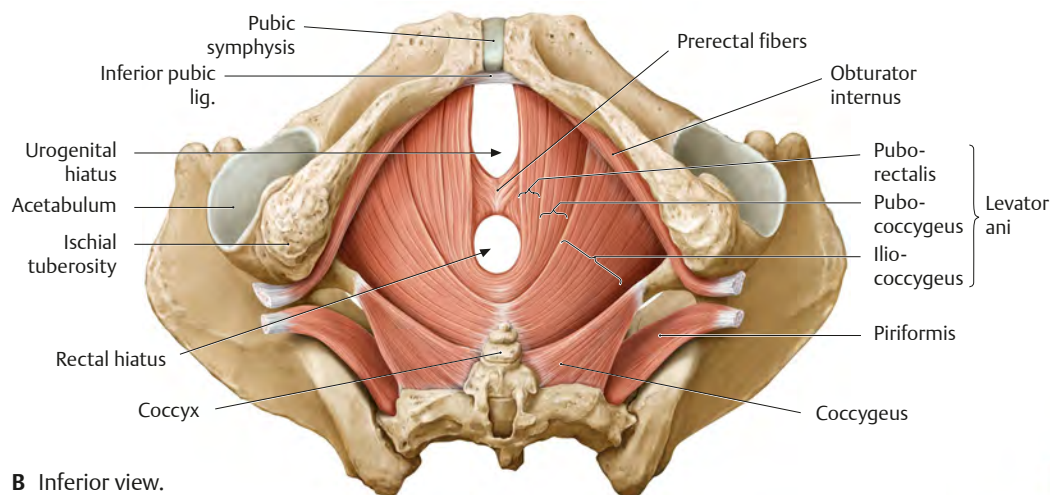
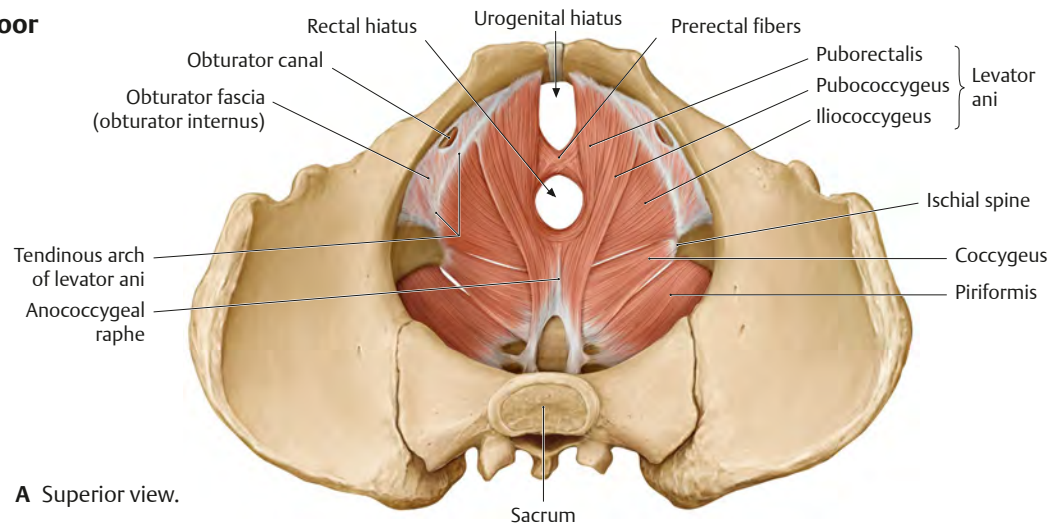
Fig. 19.12 Pelvic ligament attachment sites on the coxal bone

Left coxal bone, medial view. Ligament attachments are shown in green.

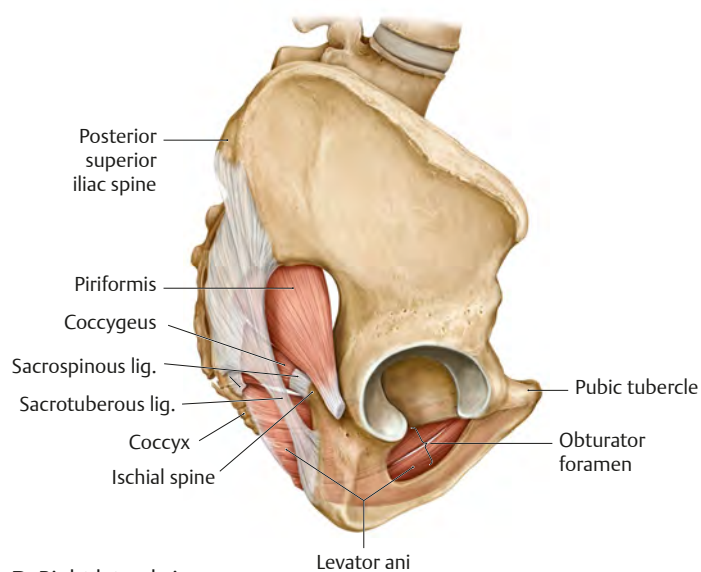


Muscles of the Pelvic Floor & Perineum

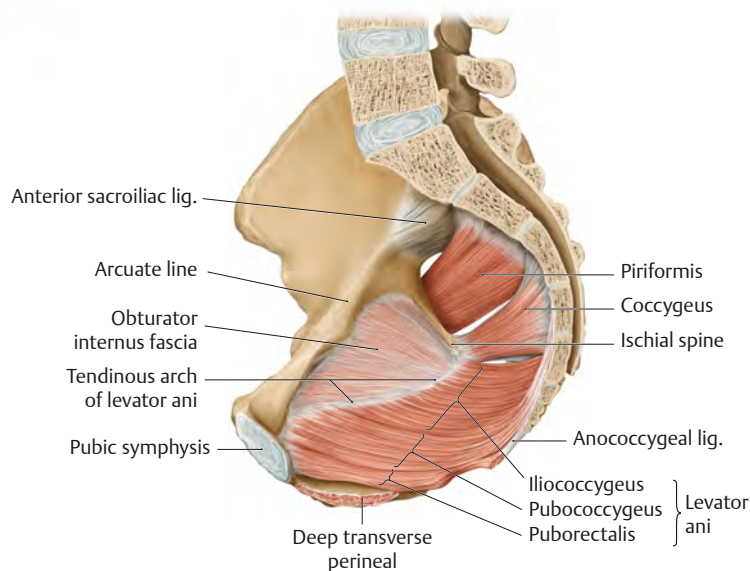
Fig. 19.13 Muscles of the pelvic floor



B Inferior view.



D Right lateral view.



C Medial view of right hemipelvis.

Fig. 19.14 Muscles and fascia of the pelvic floor and perineum, in situ

Lithotomy position. Removed on left side: Superficial perineal (Colles') fascia, inferior fascia of the pelvic diaphragm, and obturator fascia.

Note: The green arrows are pointing forward to the anterior recess of the ischioanal fossa.

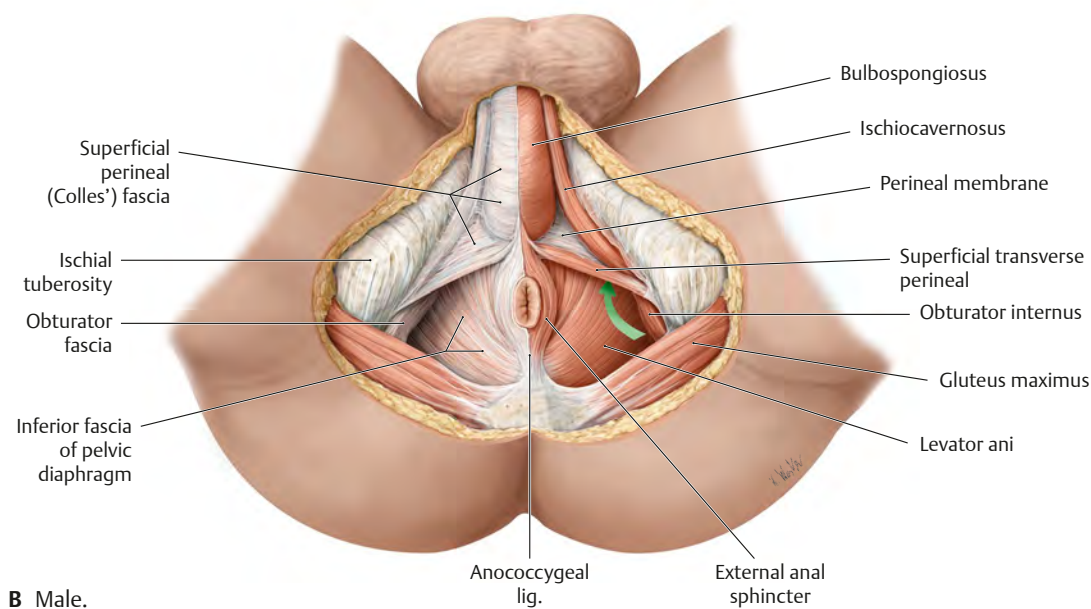
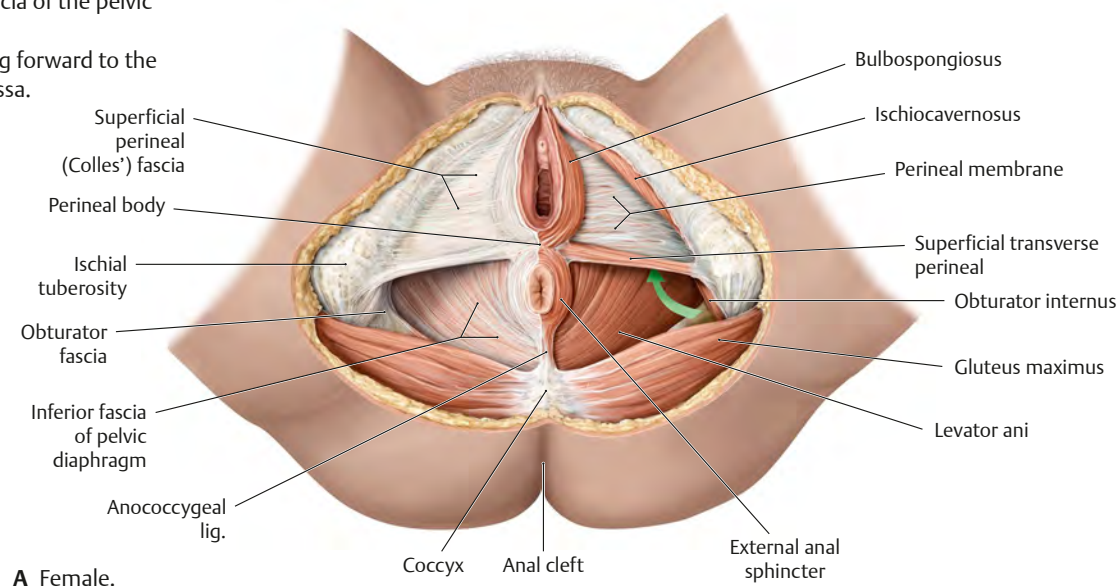
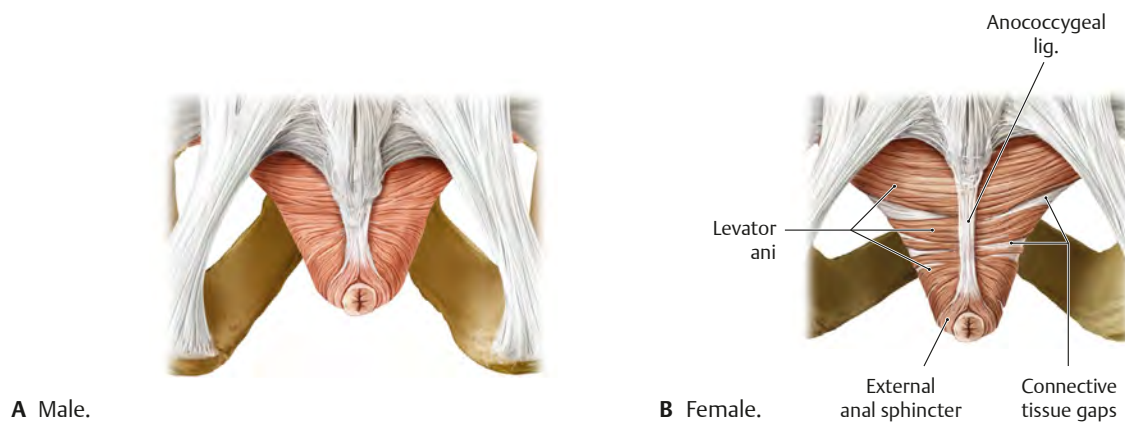


Fig. 19.15 Gender-related differences in structure of the levator ani

Posterior view. Note the connective tissue gaps between muscular parts of the levator ani in the female.



Pelvic Floor & Perineal Muscle Facts

Fig. 19.16 Muscles of the pelvic floor
Superior view.

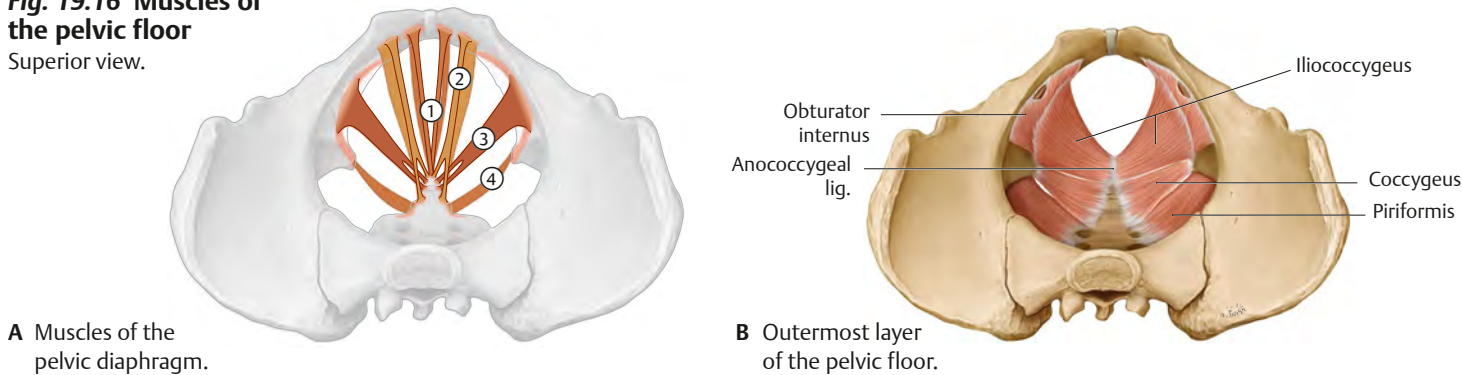


Table 19.2		Muscles of the pelvic floor			
Muscle		Origin	Insertion	Innervation	Action
Muscles of the pelvic diaphragm					
Levator ani	① Puborectalis	Superior pubic ramus (both sides of pubic symphysis)	Anococcygeal lig.	Nerve to levator ani (S4), inferior rectal n.	Pelvic diaphragm: Supports pelvic viscera
	② Pubococcygeus	Pubis (lateral to origin of puborectalis)	Anococcygeal lig., coccyx		
	③ Iliococcygeus	Internal obturator fascia of levator ani (tendinous arch)			
④ Coccygeus		Lateral surface of coccyx and S5 segment	Ischial spine	Direct branches from sacral plexus (S4–S5)	Supports pelvic viscera, flexes coccyx
Muscles of the pelvic wall (parietal muscles)					
Piriformis*		Sacrum (pelvic surface)	Femur (apex of greater trochanter)	Direct branches from sacral plexus (S1–S2)	Hip joint: External rotation, stabilization, and abduction of flexed hip
Obturator internus*		Obturator membrane and bony boundaries (inner surface)	Femur (greater trochanter, medial surface)	Direct branches from sacral plexus (L5–S1)	Hip joint: External rotation and abduction of flexed hip
*The piriformis and obturator internus are considered muscles of the hip (see p. 426). The female and male external genitalia are shown on pp. 262–265.					

Fig. 19.17 Muscles of the perineum
Inferior view.

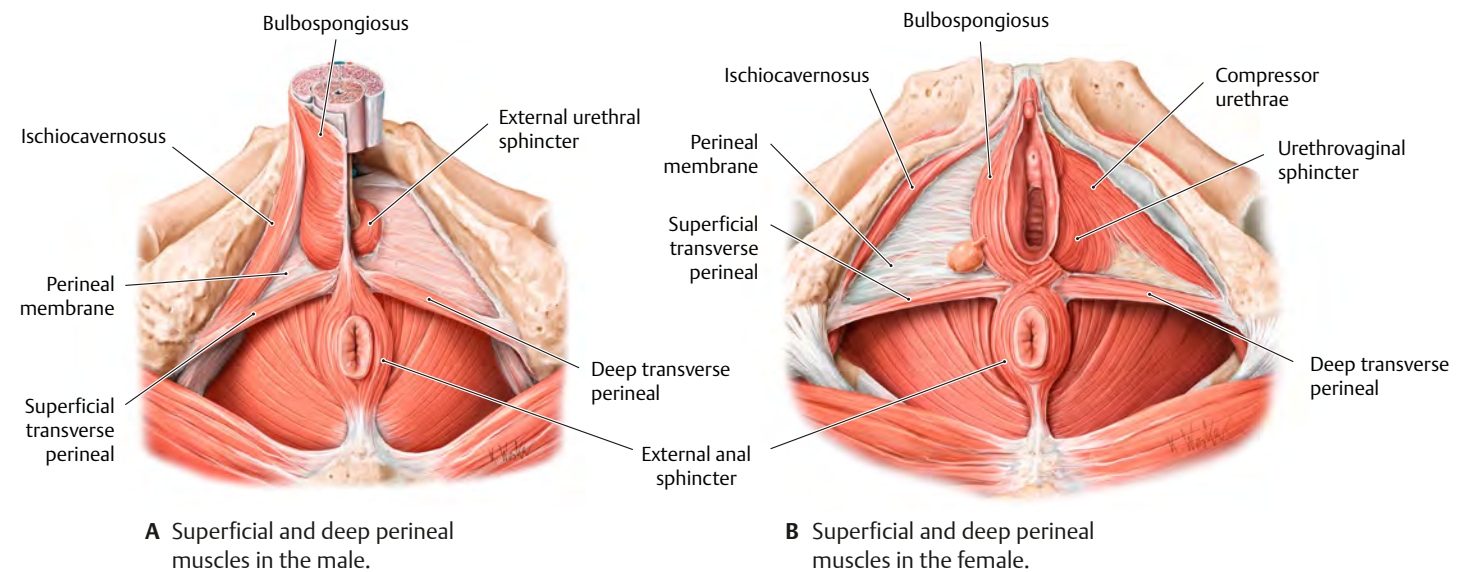


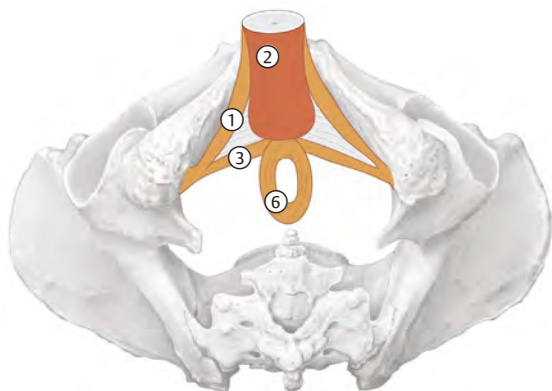
Table 19.3

Muscles of the perineum

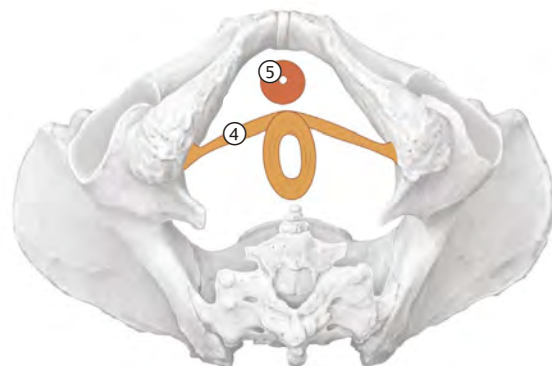
Muscle	Origin	Insertion	Innervation	Action
① Ischiocavernosus	Ischial ramus	Crus of clitoris or penis	Pudendal n. (S2–S4)	Maintains erection by squeezing blood into corpus cavernosum of clitoris or penis
② Bulbospongiosus	Runs anteriorly from perineal body to clitoris (females) or penile raphe (males)			Females: Compresses greater vestibular gland Males: Assists in erection
③ Superficial transverse perineal	Ischiopubic ramus	Perineal body		Helps hold perineal body in median plane, holds the pelvic organs in place, and supports visceral canals through the muscles of the perineum
④ Deep transverse perineal*	Ishiopubic ramus	Perineal body and external anal sphincter		
⑤ External urethral sphincter	Encircles urethra (division of deep transverse perineal muscle), in males ascends anteriorly to neck of the bladder; in females, some fibers surround the vagina as the urethrovaginal sphincter , others extend laterally as the compressor urethrae (See Figs. 21.9 and 21.11)			Closes urethra
⑥ External anal sphincter	Encircles anus (runs posteriorly from perineal body to anococcygeal lig.)			Closes anus

* Typically, this muscle is not developed in females and is replaced by smooth muscle tissue. When developed, it provides dynamic support to the pelvic organs.

Fig. 19.18 Muscles of the male perineum

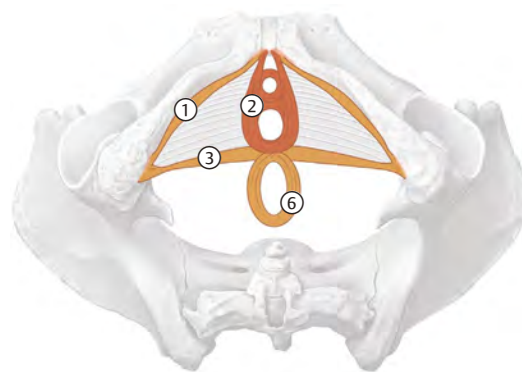


A Muscles of the superficial pouch in the male.

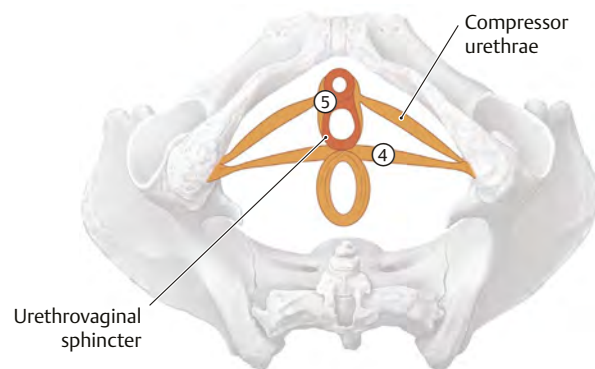


B Muscles of the deep pouch in the male.

Fig. 19.19 Muscles of the female perineum



A Muscles of the superficial pouch in the female.



B Muscles of the deep pouch in the female.

20 Spaces

Contents of the Pelvis

Fig. 20.1 Male pelvis
Parasagittal section, viewed from the right side.

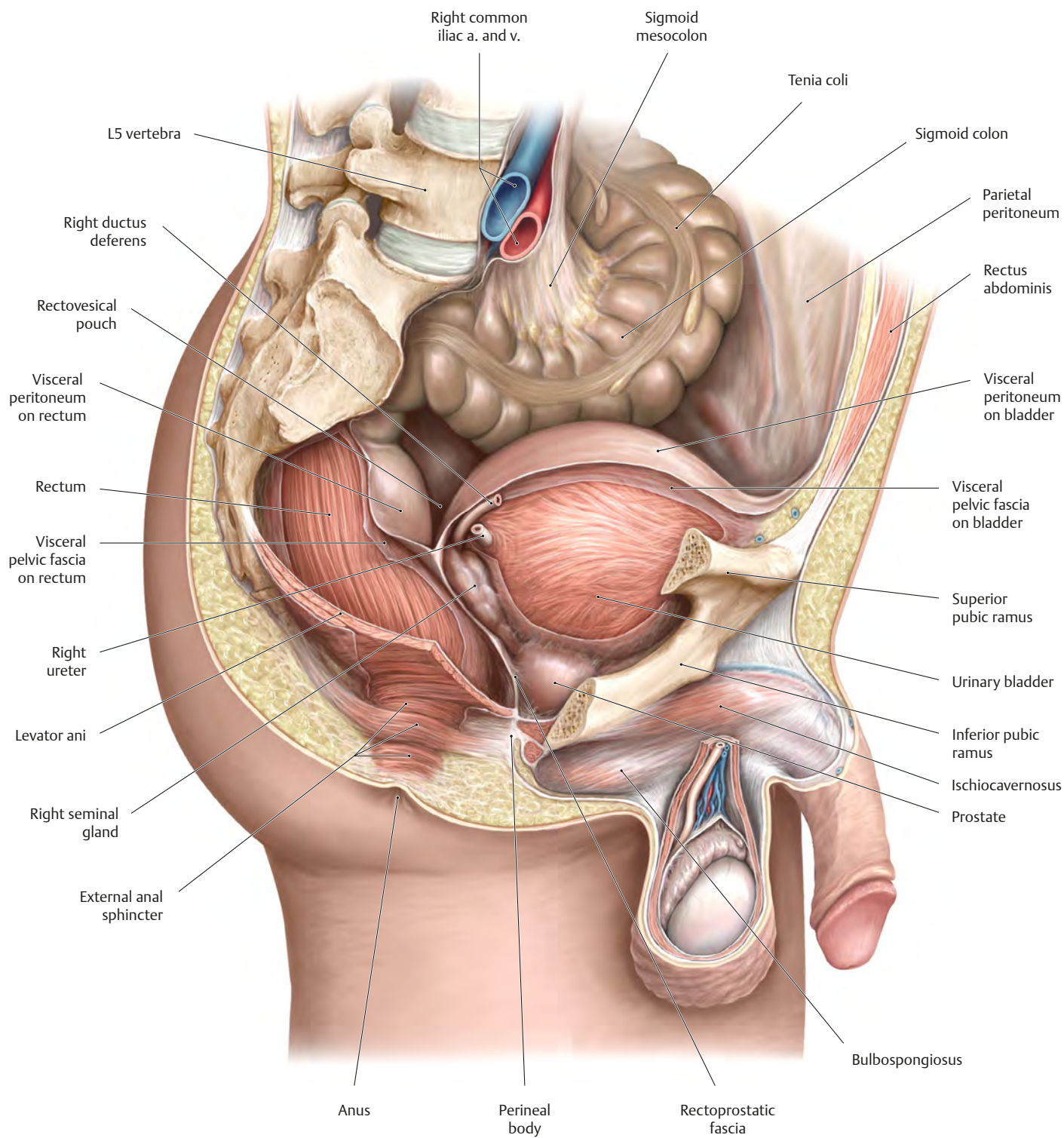
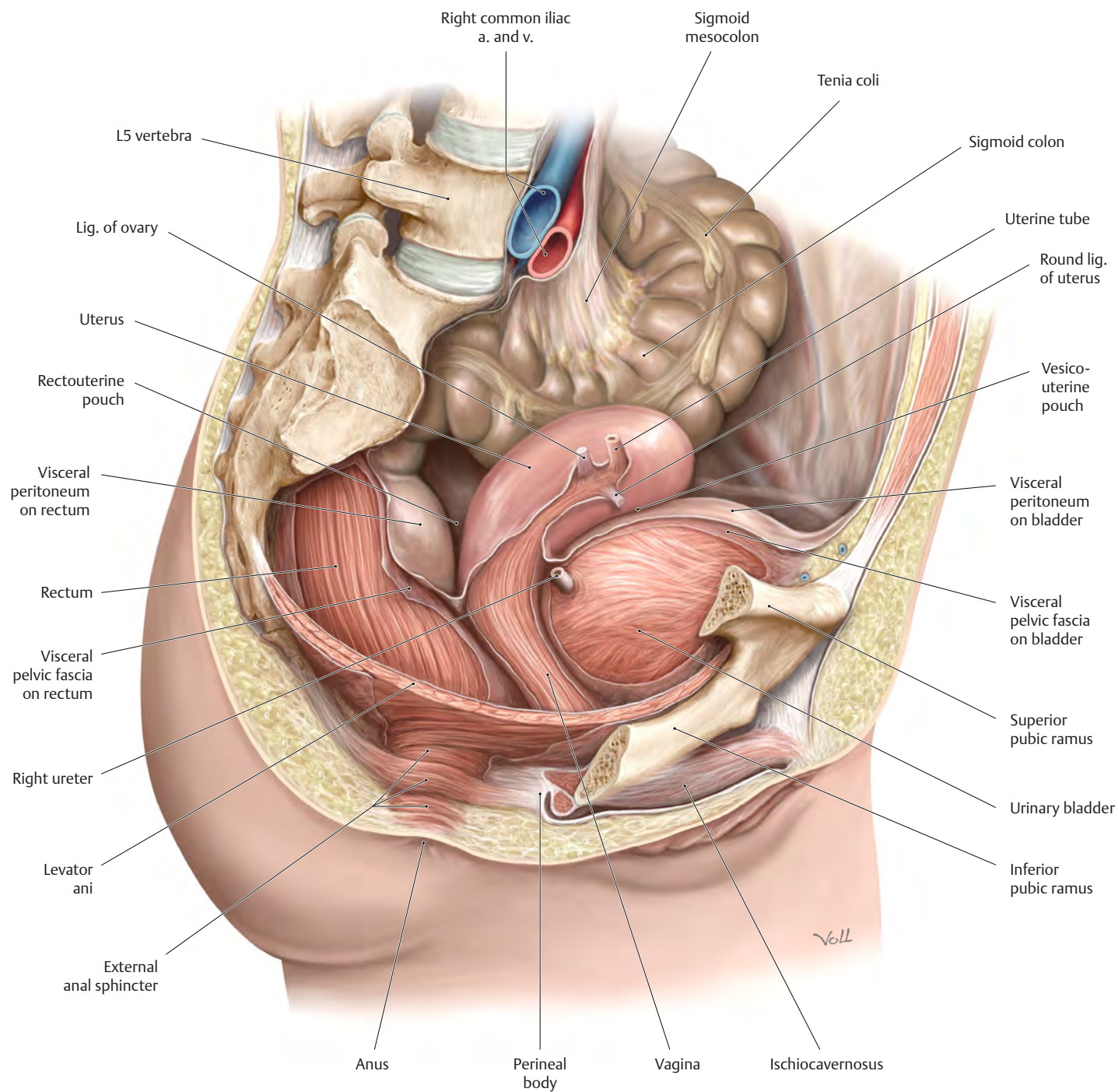


Fig. 20.2 Female pelvis

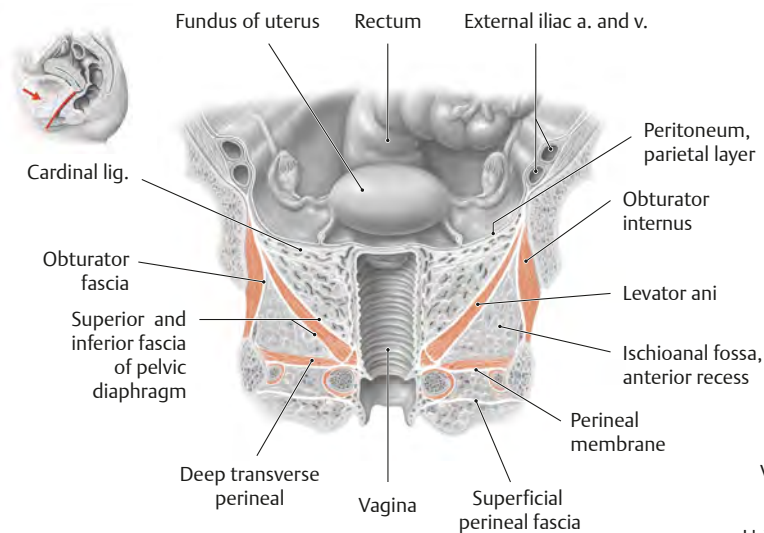
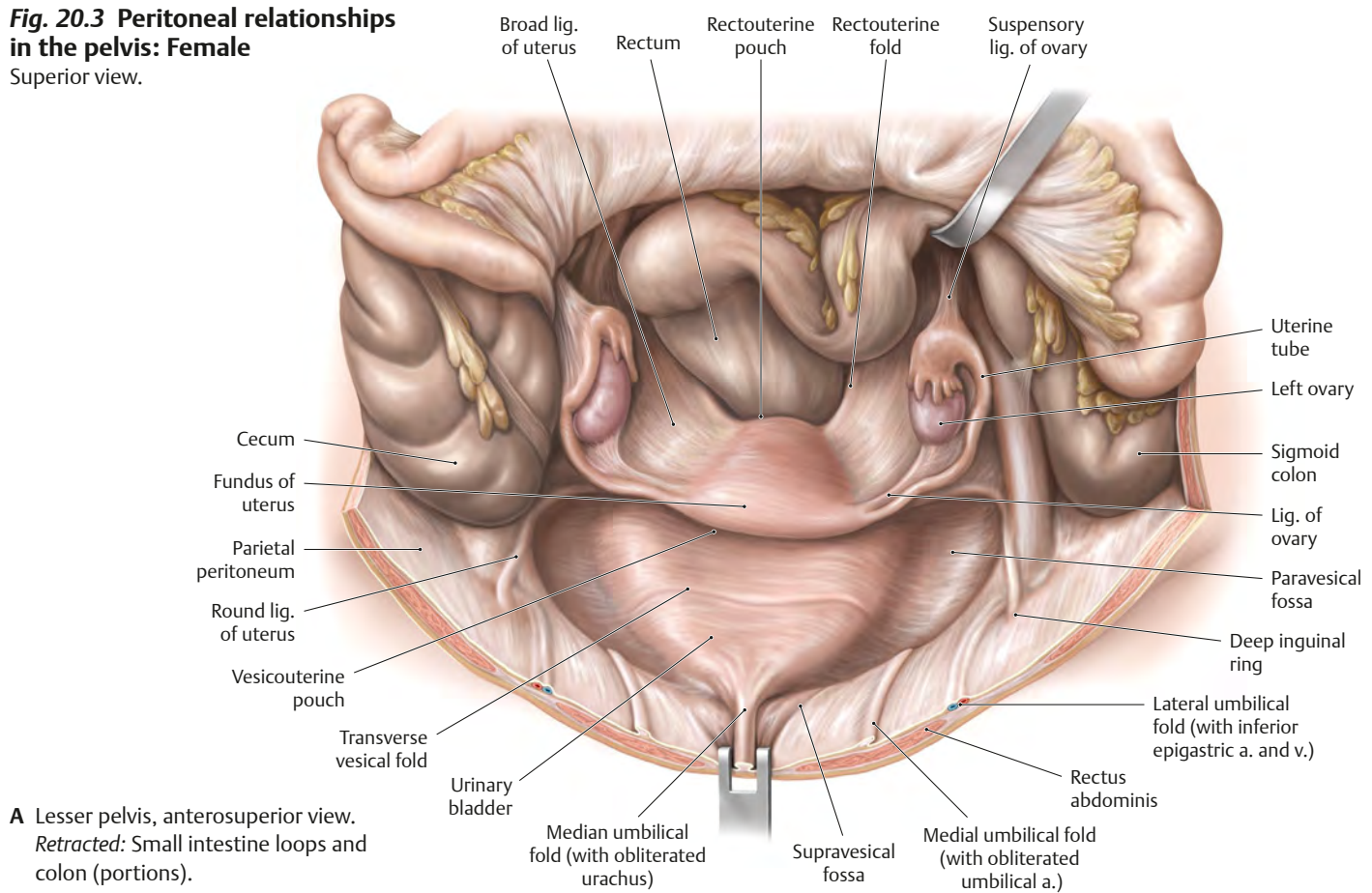
Parasagittal section, viewed from the right side.



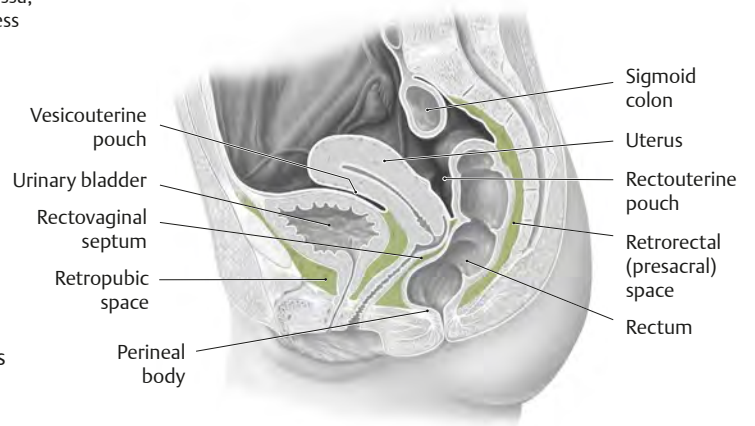
Peritoneal Relationships

Fig. 20.3 Peritoneal relationships in the pelvis: Female

Superior view.



C Peritoneal and subperitoneal spaces (green) in the pelvis. Midsagittal section, viewed from the left side.



Pelvis & Perineum

The *pelvis* is the region of the body inferior to the abdomen, surrounded by the pelvic girdle. The *false*, or greater, *pelvis* is immediately inferior to the abdominal cavity, between the iliac alae, and superior to the pelvic inlet. The *true*, or lesser, *pelvis* is found between the pelvic inlet and the pelvic outlet and extends inferiorly to the pelvic diaphragm (levator ani and coccygeus), a muscular sling attached to the boundaries of the

pelvic outlet. The *perineum* is the inferior most portion of the trunk, between the thighs and buttocks, extending from the pubis to the coccyx and superiorly to the pelvic diaphragm. The *superficial perineal* pouch lies between the membranous layer of the subcutaneous tissue (Colles' fascia) and the perineal membrane. The *deep perineal* pouch lies between the perineal membrane and the inferior fascia of the pelvic diaphragm.

Table 20.1 Divisions of the pelvis and perineum

The levels of the pelvis are determined by bony landmarks (iliac alae and pelvic inlet/brim). The contents of the perineum are separated from the true pelvis by the pelvic diaphragm and two fascial layers.

Iliac crest

Pelvis	False pelvis	- Ileum (coils) - Cecum and appendix - Sigmoid colon - Common and external iliac aa. and vv. - Lumbar plexus (brs.)
	Pelvic inlet	
Pelvis	True pelvis	- Distal ureters - Urinary bladder - Rectum ♀: Vagina, uterus, uterine tubes, and ovaries ♂: Ductus deferens, seminal gland, and prostate - Internal iliac a. and v. and brs. - Sacral plexus - Inferior hypogastric plexus

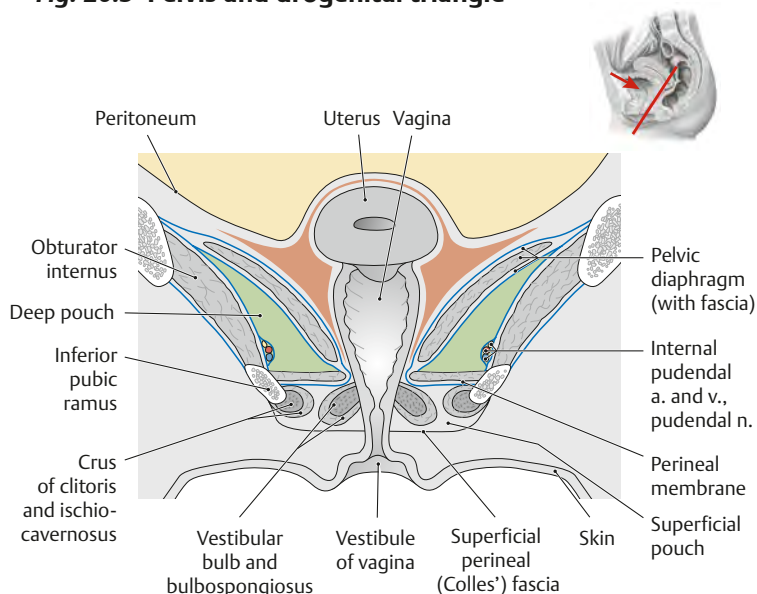
Pelvic diaphragm (levator ani & coccygeus)

Perineum	Deep pouch	- Sphincter urethrae and deep transverse perineal mm. - Urethra (membranous) - Vagina - Rectum - Bulbourethral gland - Ischioanal fossa - Internal pudendal a. and v., pudendal n. and brs.
	Perineal membrane	

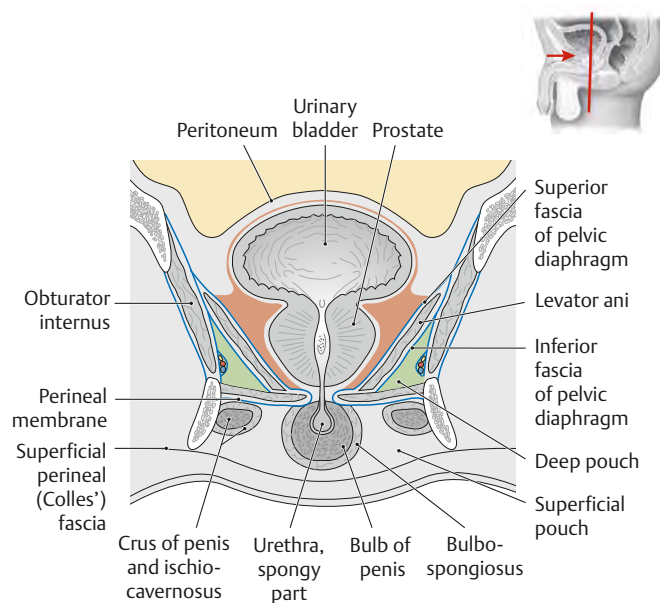
Perineum	Superficial pouch	- Ischiocavernosus, bulbospongiosus, and superficial transverse perineal mm. - Urethra (penile) - Clitoris and penis - Internal pudendal a. and v., pudendal n. and branches
	Superficial perineal (Colles') fascia	
Perineum	Subcutaneous perineal space	Fat

Skin

Fig. 20.5 Pelvis and urogenital triangle



A Female. Oblique section.

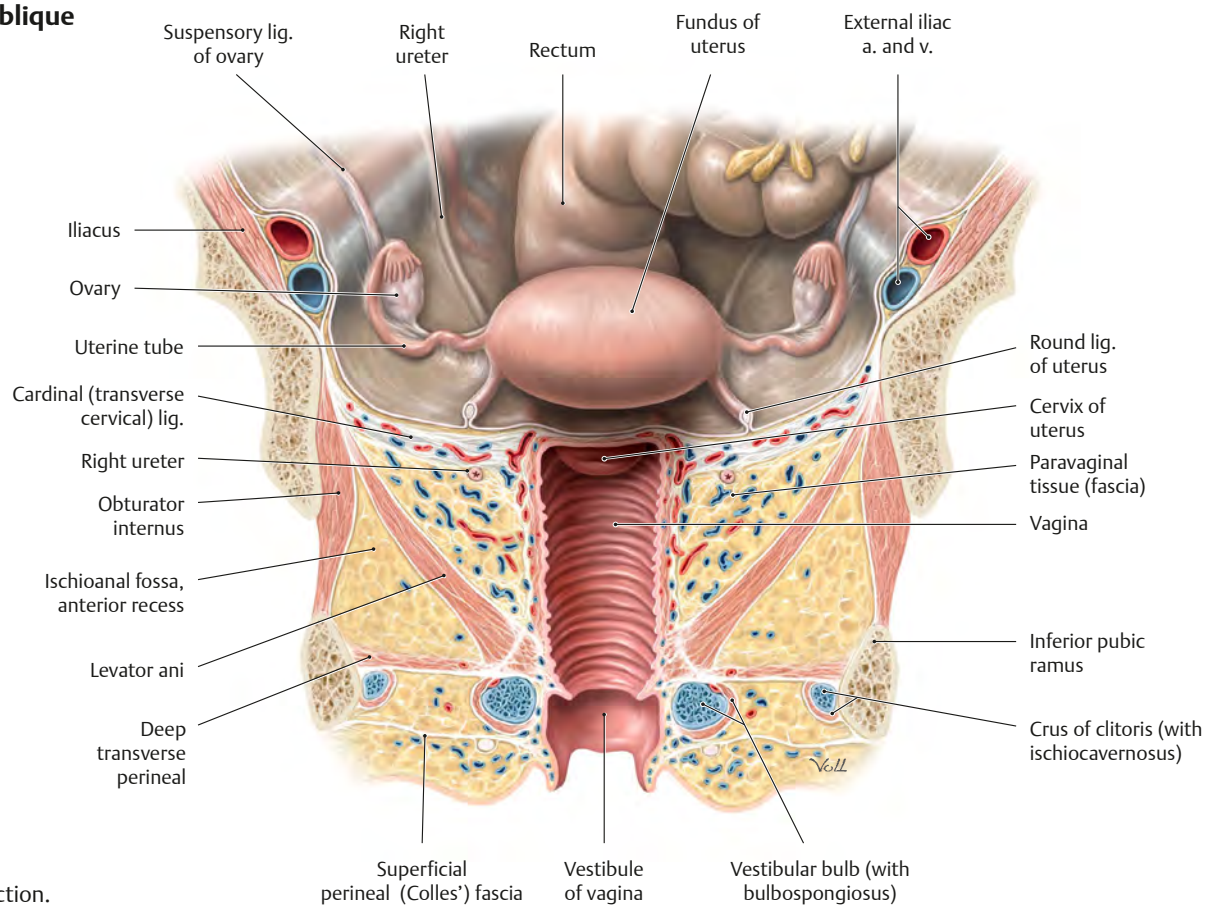


B Male. Coronal section.

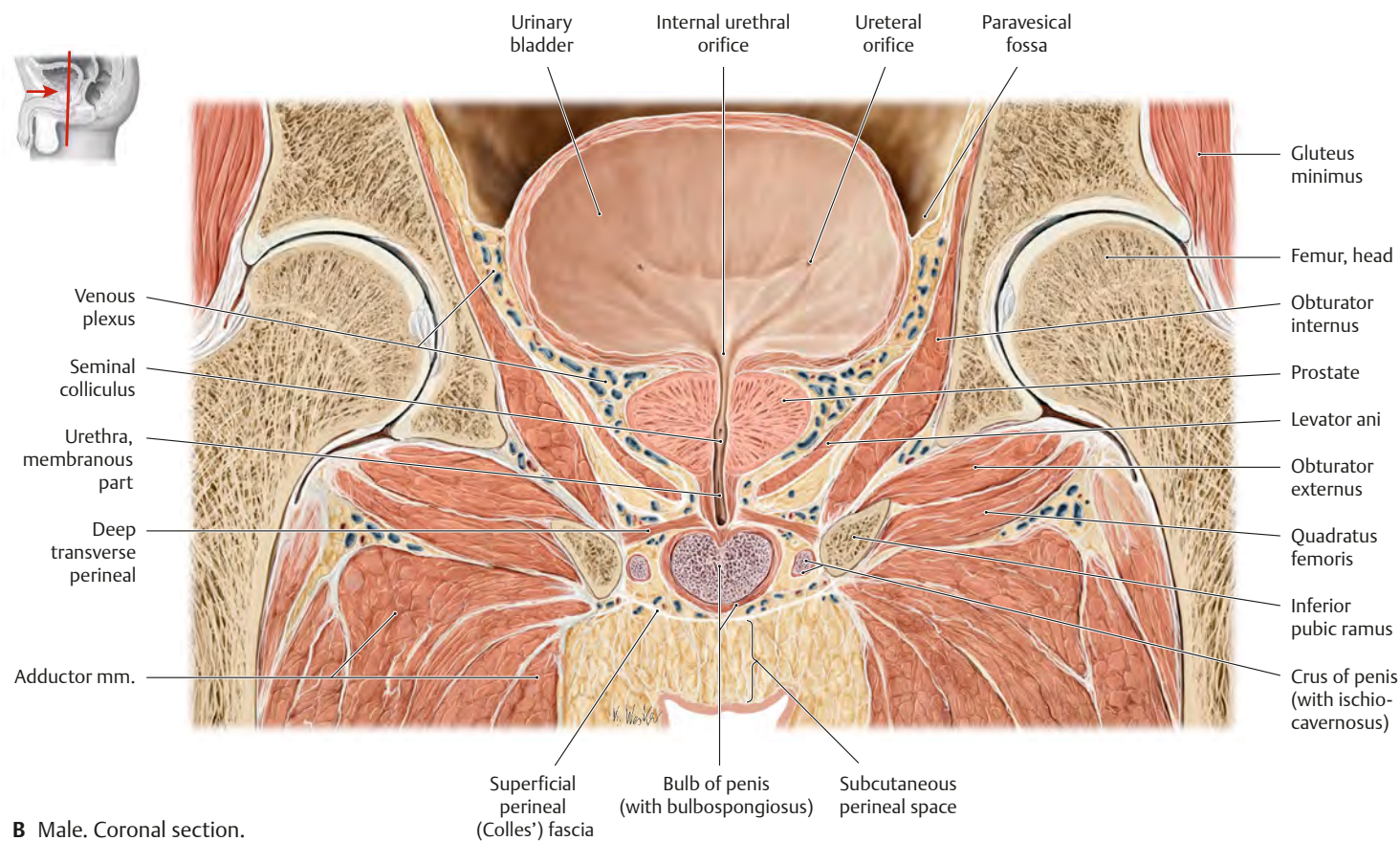
- Peritoneal cavity
- Subperitoneal space
- Ischioanal fossa
- Visceral pelvic fascia
- Parietal pelvic fascia

Fig. 20.6 Pelvis: Oblique section

Anterior view.



A Female. Oblique section.

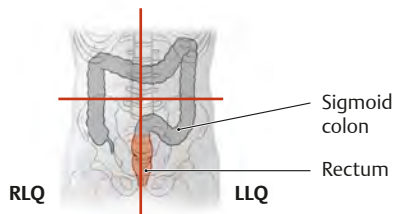


B Male. Coronal section.

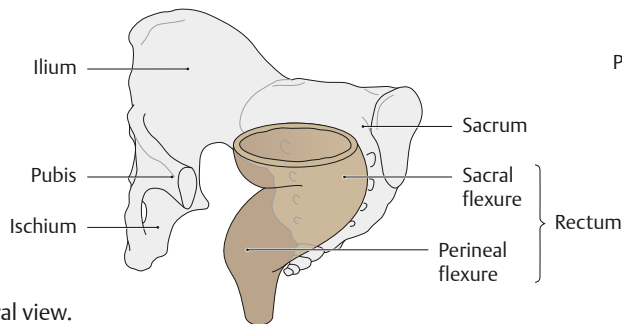
21 Internal Organs

Rectum & Anal Canal

Fig. 21.1 Rectum: Location



A Anterior view.



B Left anterolateral view.

Fig. 21.2 Closure of the rectum

Left lateral view. The puborectalis acts as a muscular sling that kinks the anorectal junction. It functions in the maintenance of fecal continence.

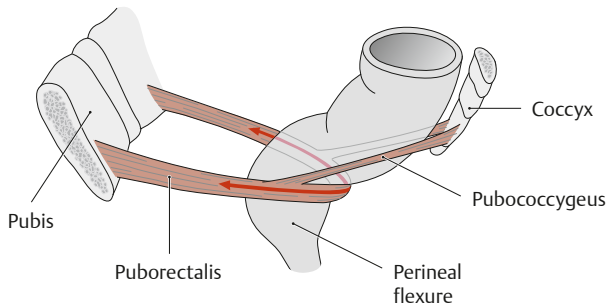


Fig. 21.3 Rectum in situ

Coronal section, anterior view of the female pelvis. The upper third of the rectum is covered with visceral peritoneum on its anterior and lateral sides. The middle third is covered only anteriorly and the lower third is inferior to the parietal peritoneum.

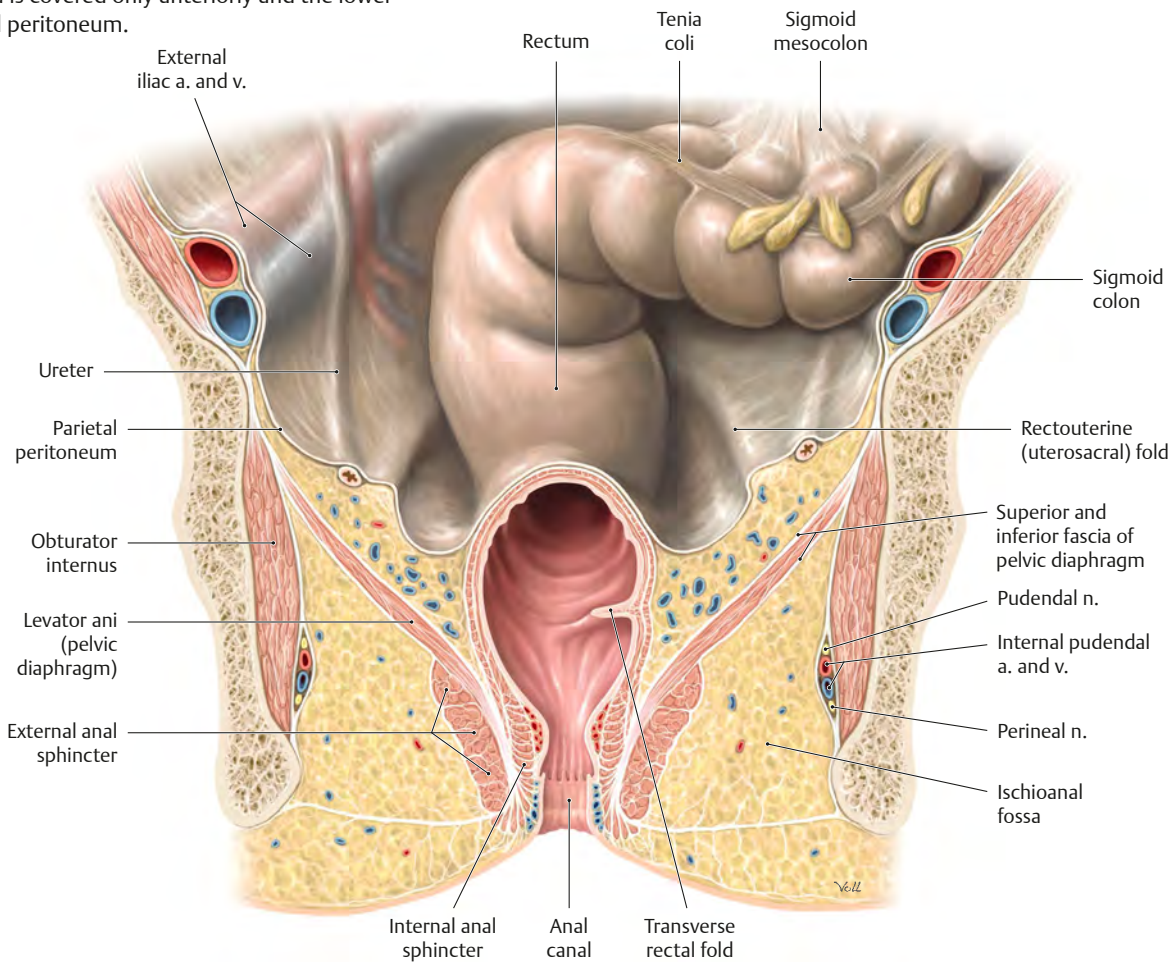


Fig. 21.4 Rectum and anal canal
Coronal section, anterior view with the anterior wall removed.

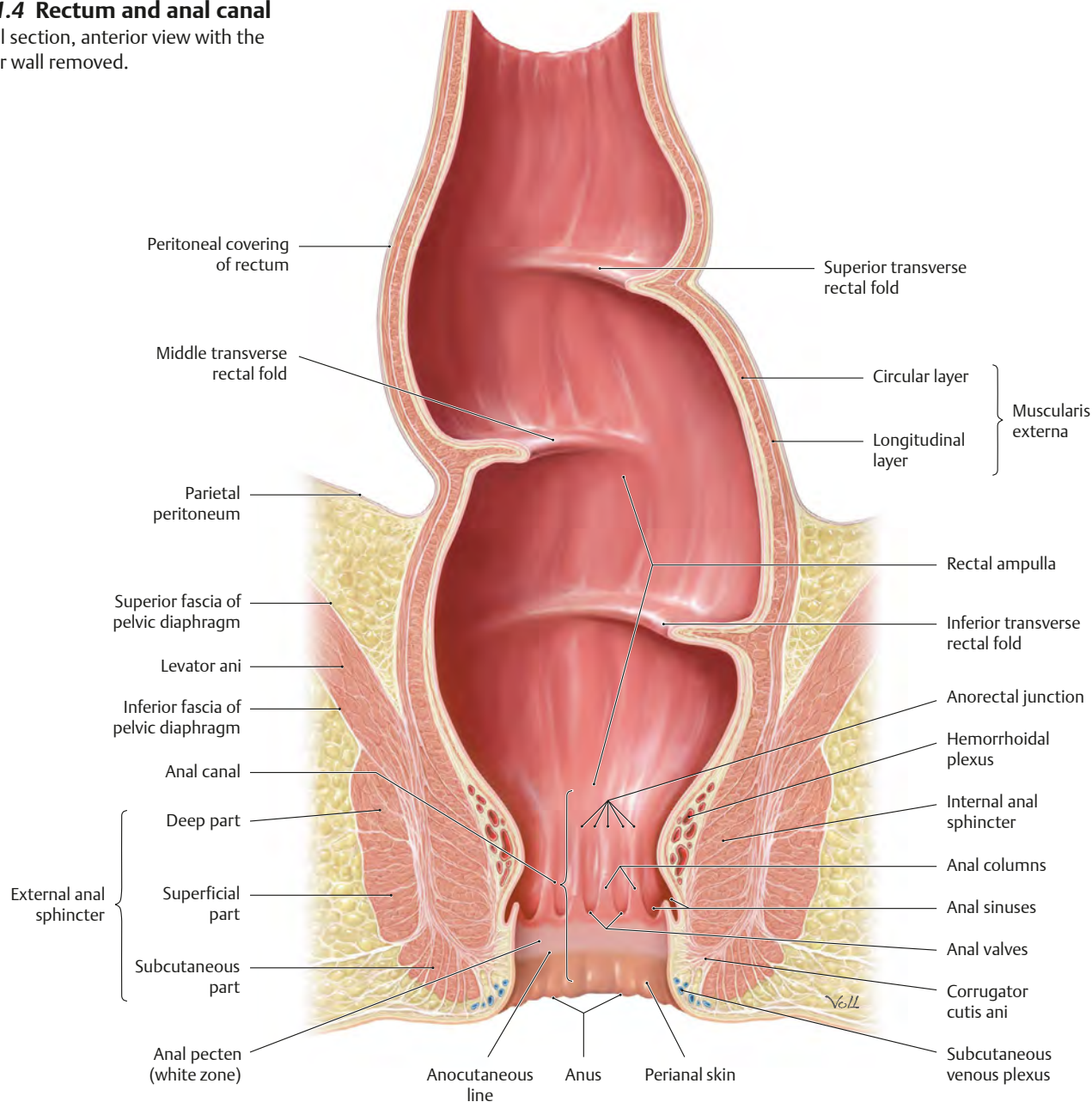


Table 21.1 Regions of the rectum and anal canal		
Region		Epithelium
① Rectum		Colon-like with crypts; simple columnar with goblet cells
Anal canal	② Columnar zone	Stratified squamous, nonkeratinized
	③ Anal pecten	Stratified squamous, keratinized with sebaceous glands
	④ Cutaneous zone	Stratified squamous, keratinized with sebaceous glands, hairs, and sweat glands
⑤ Perianal skin (pigmented)		Stratified squamous, keratinized with sebaceous glands, hairs, and sweat glands

Fig. 21.5 Ureters in situ

Anterior view, male abdomen. *Removed:* Nonurinary organs and rectal stump. The ureters descend along the posterior abdominal wall in the retroperitoneal space. On each side, they enter the pelvis after crossing the common iliac artery at its bifurcation into the external and internal arteries.

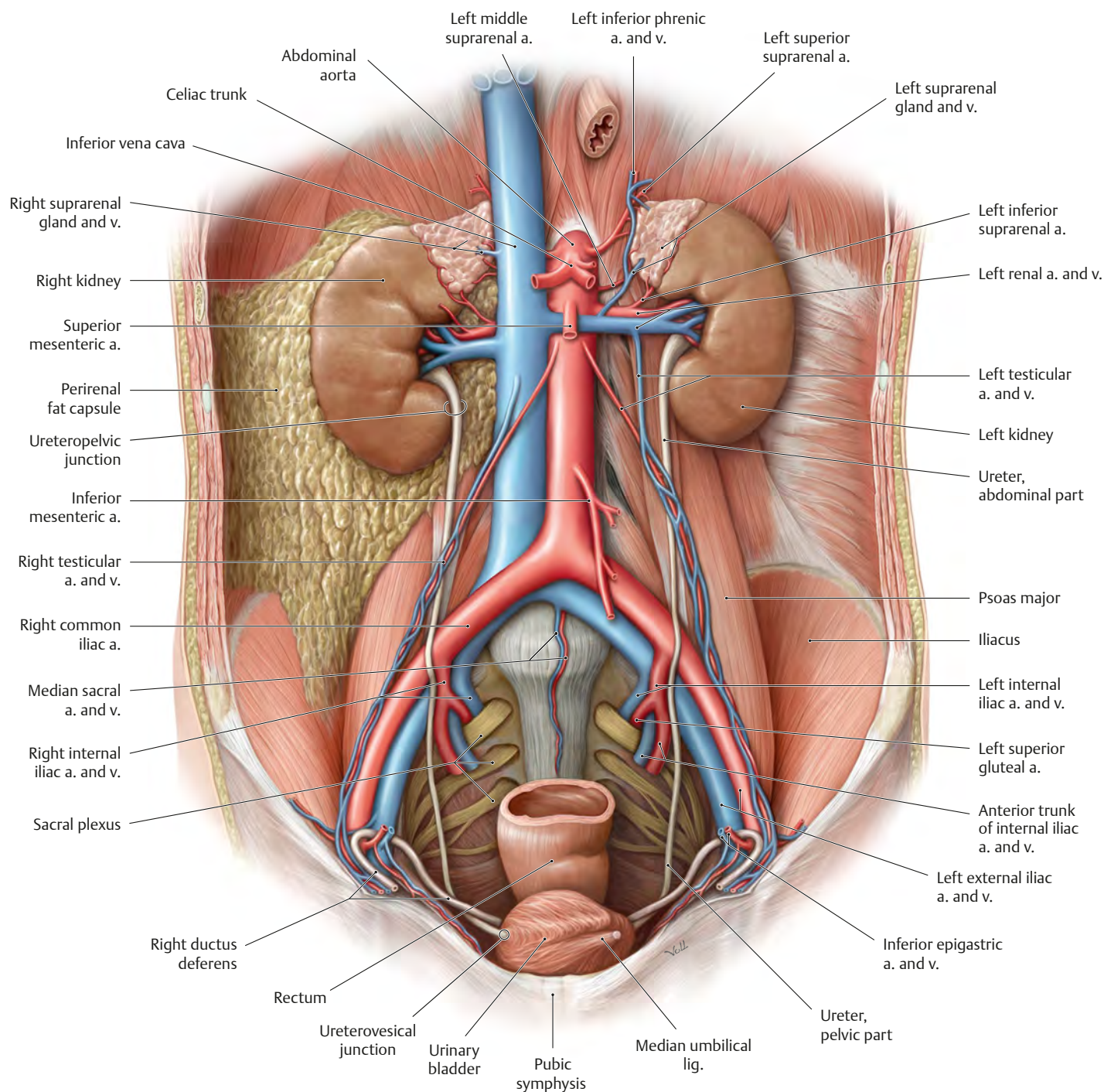
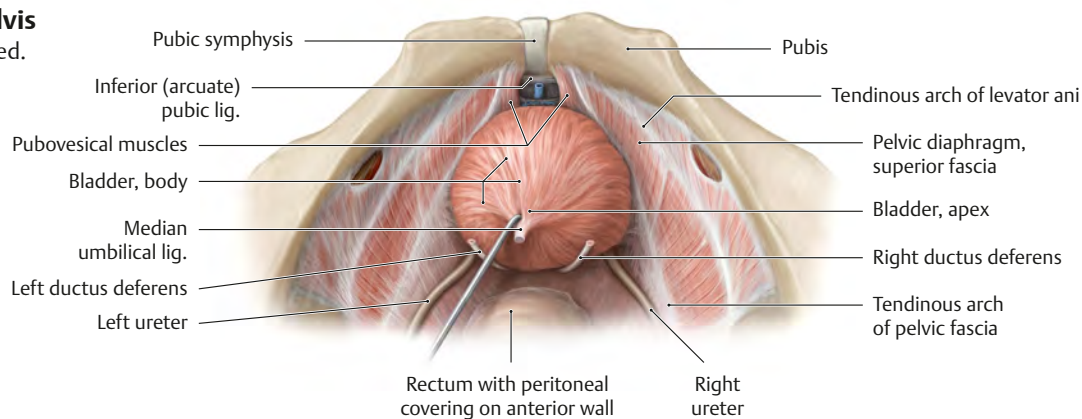


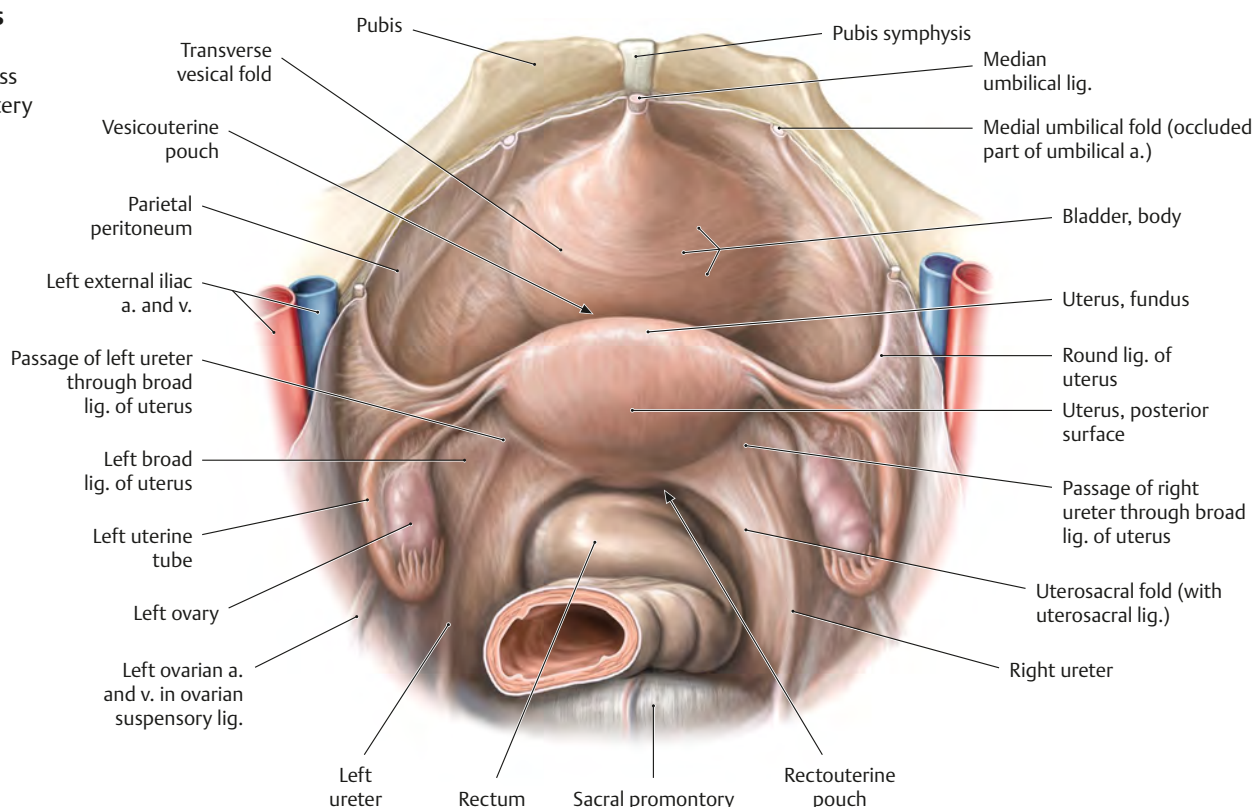
Fig. 21.6 Ureter in the male pelvis

Superior view with peritoneum removed.

**Fig. 21.7 Ureter in the female pelvis**

Superior view.

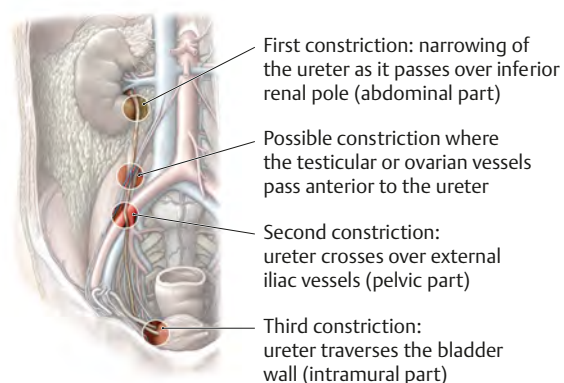
The pelvic ureters pass under the uterine artery approximately 2 cm lateral to the cervix.

**Clinical box 21.1****Anatomical constrictions of the ureter**

There are three normal *anatomical constrictions* where a pain-causing kidney stone from the renal pelvis is apt to become lodged:

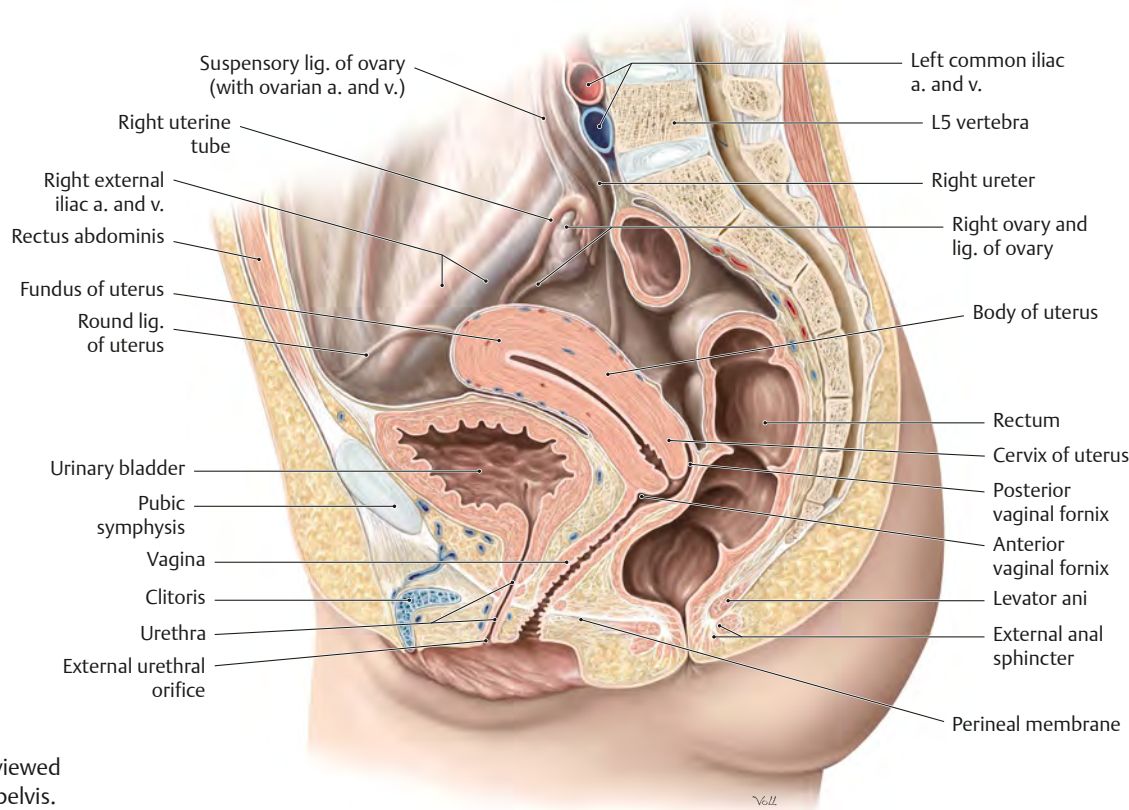
- Narrowing at the origin of the ureter from the renal pelvis (ureteropelvic junction)
- Site where the ureter crosses over the external or common iliac vessels
- Passage of the ureter through the bladder wall (ureterovesical junction).

Occasionally a *fourth constriction* can be identified where the testicular or ovarian artery and vein pass anterior to the ureter.

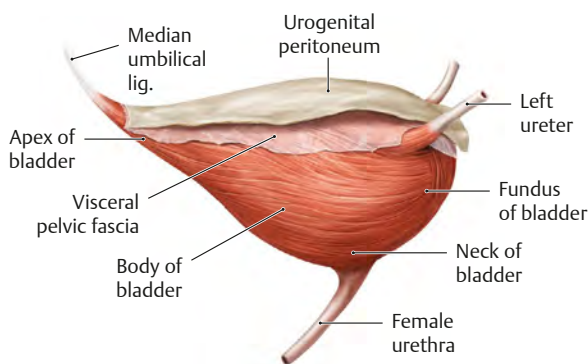


Urinary Bladder & Urethra

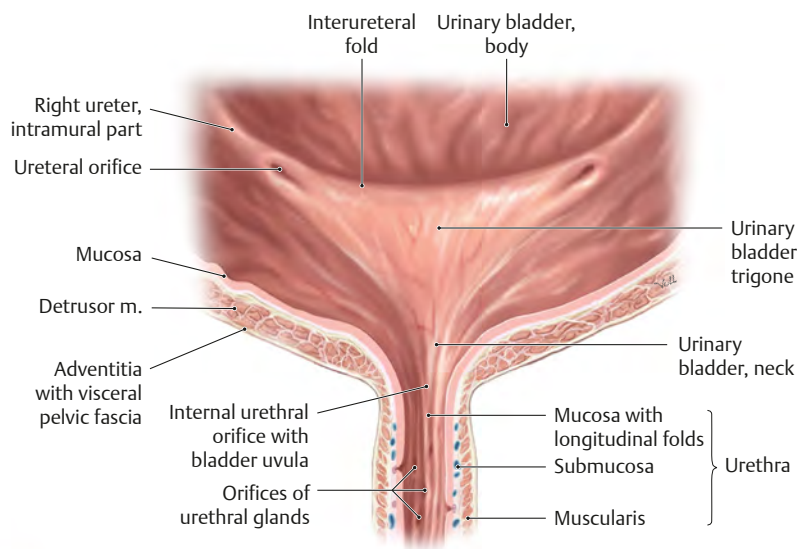
Fig. 21.8 Female urinary bladder and urethra



A Midsagittal section of pelvis, viewed from the left side. Right hemipelvis.



B Bladder and urethra, left lateral view.



C Trigone and urethra, coronal section, anterior view.

Fig. 21.9 Urethral sphincter mechanism in the female
Anterolateral view.

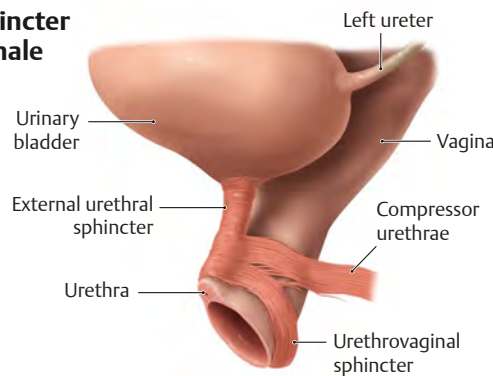
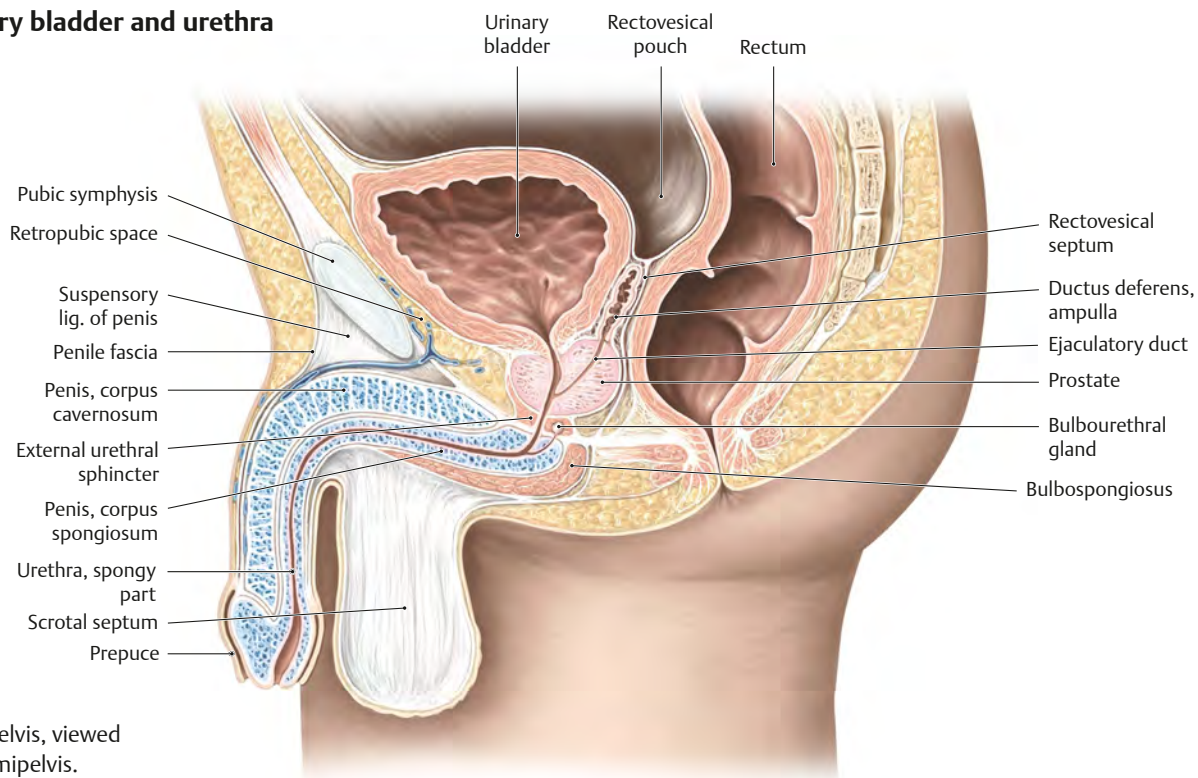
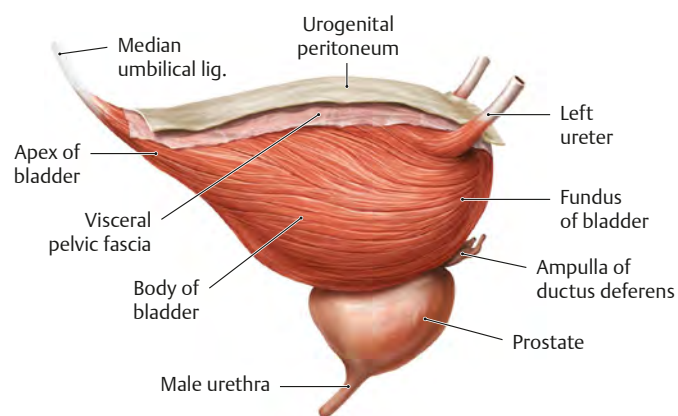
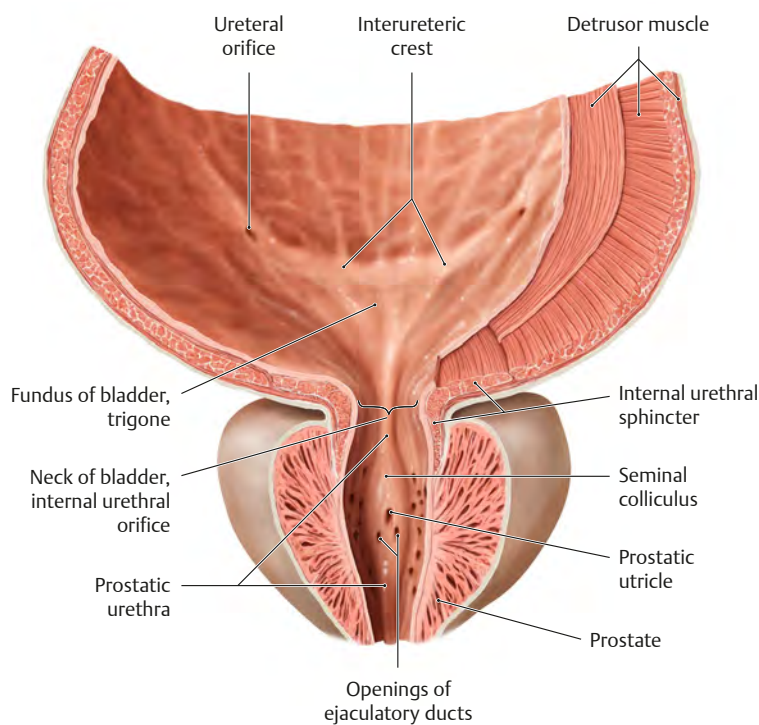
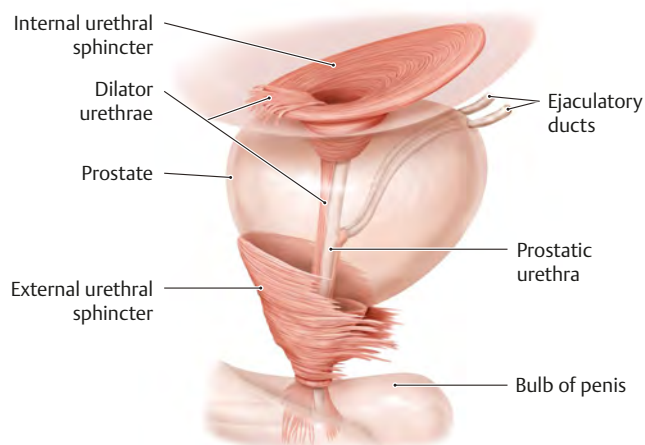


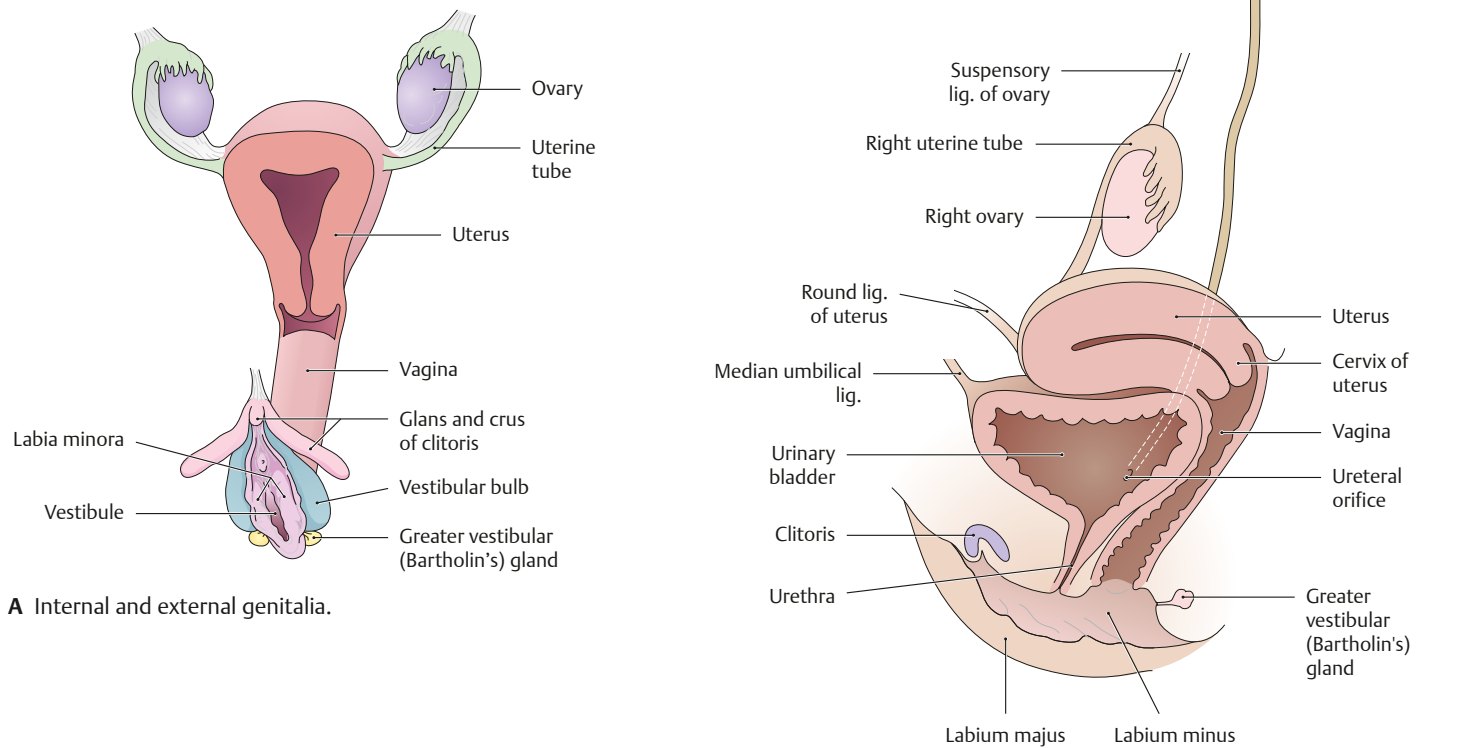
Fig. 21.10 Male urinary bladder and urethra**A** Midsagittal section of pelvis, viewed from left side. Right hemipelvis.**B** Bladder, urethra and prostate, left lateral view.**C** Trigone, urethra and prostate, coronal section, anterior view.**Fig. 21.11 Urethral sphincter mechanism in the male**
Lateral view.

Overview of the Genital Organs

The genital organs can be classified topographically (external versus internal) and functionally (Tables 21.2 and 21.3).

Table 21.2		Female genital organs	
Organ		Function	
Internal genitalia	Ovary		Germ cell and hormone production
	Uterine tube		Site of conception and transport organ for zygote
	Uterus		Organ of incubation and parturition
	Vagina (upper portion)		Organ of copulation and parturition
External genitalia	Vulva	Vagina (vestibule)	Accessory copulatory organ
		Labia majora and minora	
		Clitoris	
		Greater and lesser vestibular glands	Production of mucoid secretions
		Mons pubis	Protection of the pubic bone

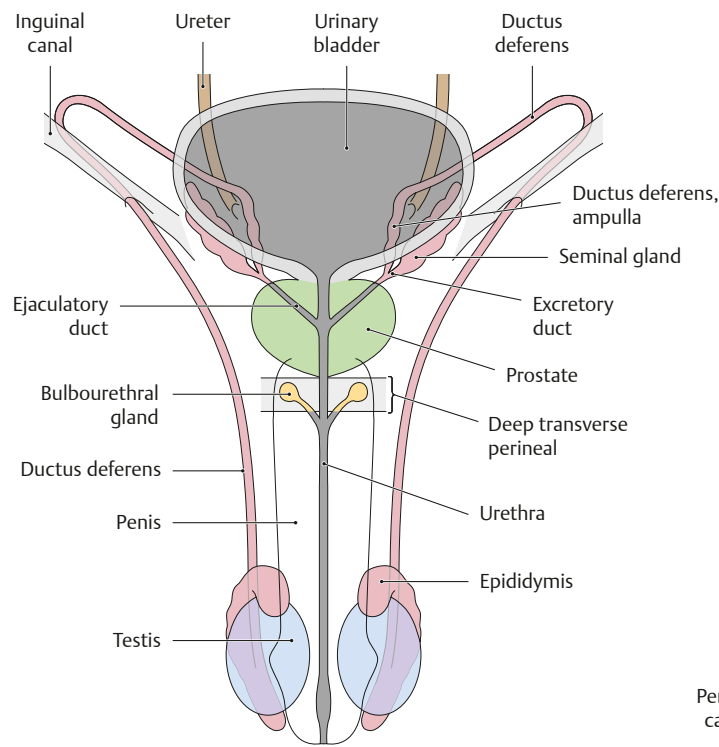
Fig. 21.12 Female genital organs



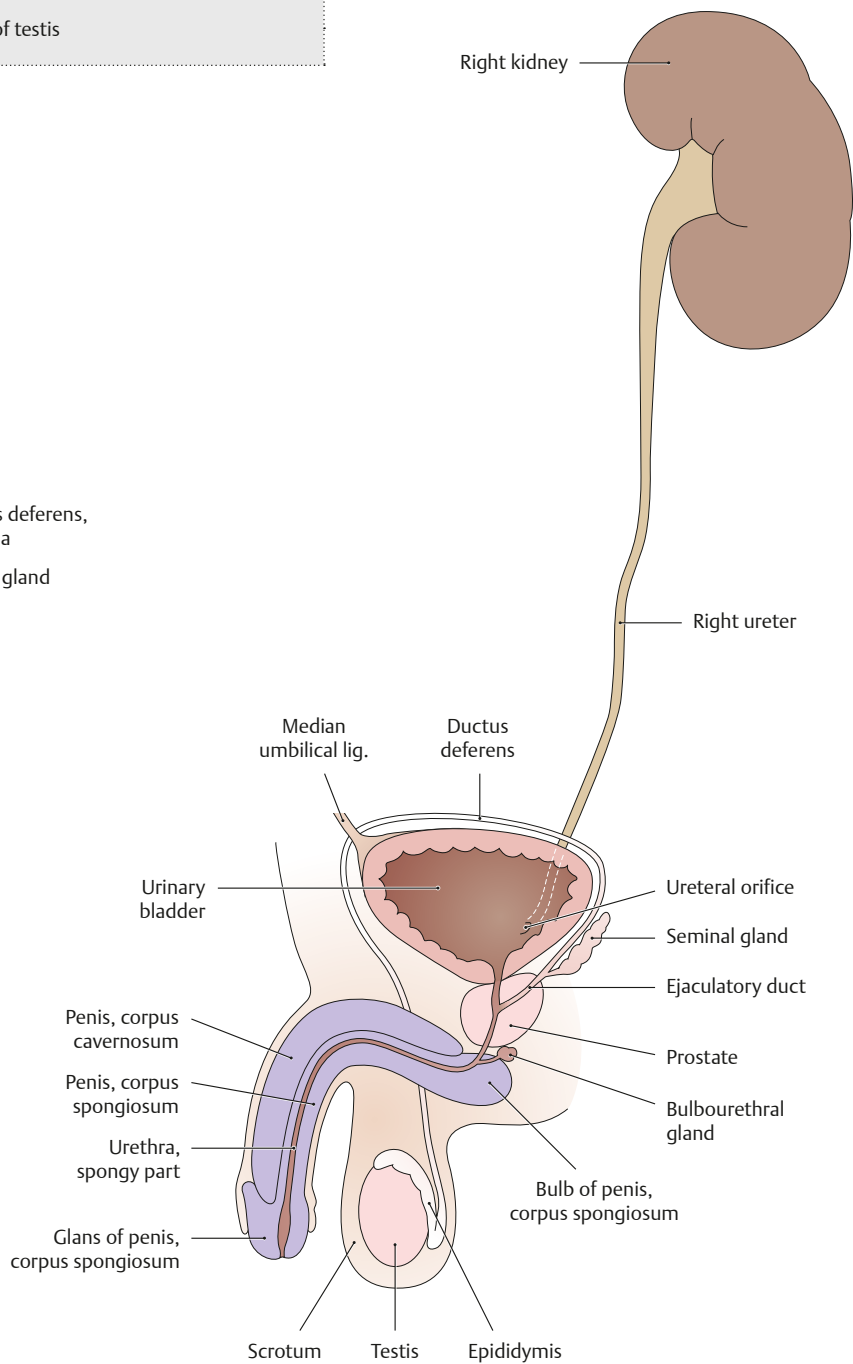
B Urogenital system. Note: The female urinary and genital tracts are functionally separate, though topographically close.

Table 21.3 Male genital organs		
	Organ	Function
Internal genitalia	Testis	Germ cell and hormone production
	Epididymis	Storage reservoir for sperm
	Ductus deferens	Transport organ for sperm
	Accessory sex glands	Prostate
		Seminal glands
		Bulbourethral gland
External genitalia	Penis	Copulatory and urinary organ
	Urethra	Conduit for urine and semen
	Scrotum	Protection of testis
	Coverings of the testis	

Fig. 21.13 Male genital organs



A Seminiferous structures.



B Urogenital system. Note: The male urethra serves as a common urinary and genital passage.

Uterus & Ovaries

Fig. 21.14 The broad ligament

Regions of the broad ligament, sagittal section. The uterus and ovaries are suspended by the broad ligament of the uterus, which is composed of a double layer of peritoneum, arranged as a combination of mesenteries: the mesosalpinx, mesovarium, and mesometrium.

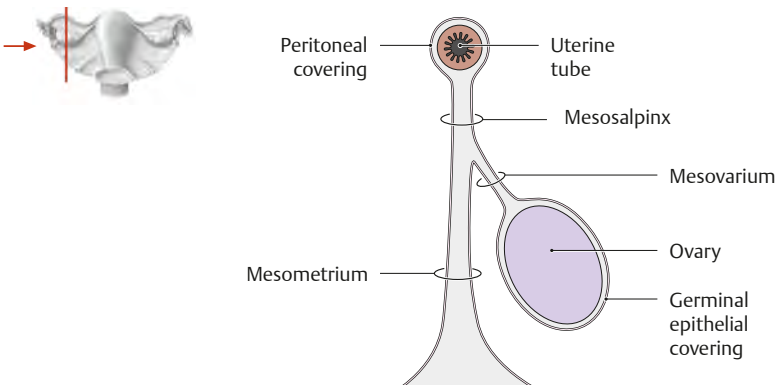


Fig. 21.15 Ovary

Right ovary, posterior view.

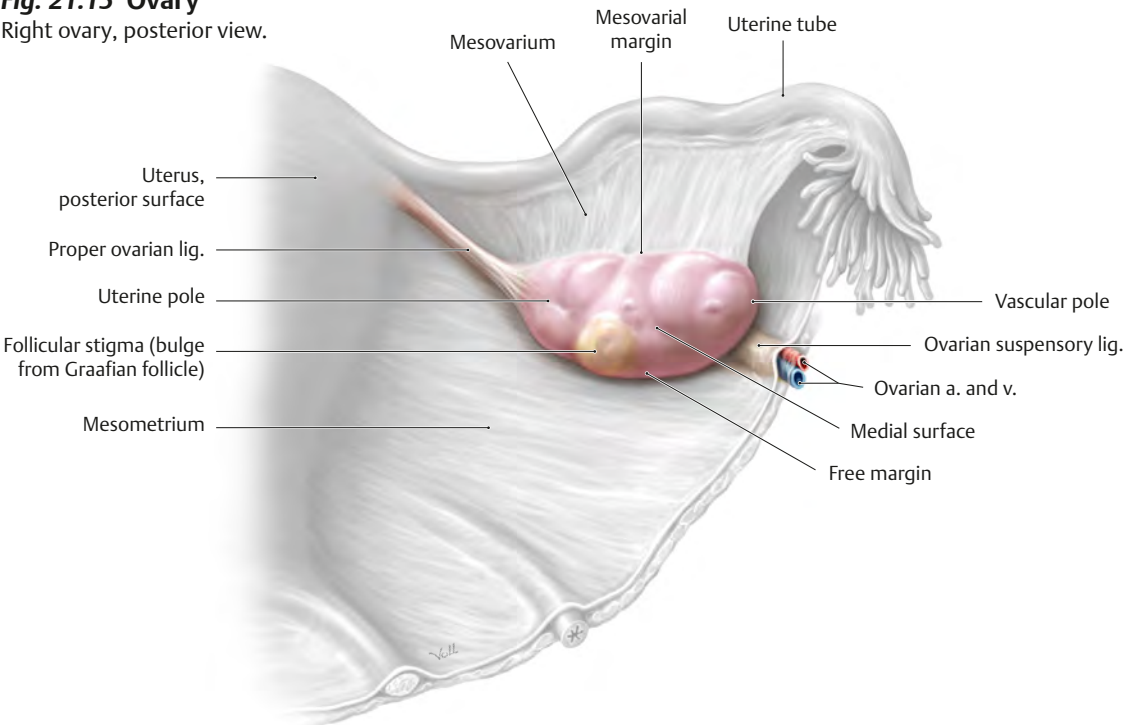


Fig. 21.16 Normal curvature and position of the uterus

Midsagittal section, left lateral view. The position of the uterus can be described in terms of:

- ① Flexion, the angle between the longitudinal cervical axis and the longitudinal uterine axis; the normal position is antelexion.
- ② Version, the angle between the longitudinal cervical axis and longitudinal vaginal axis; the normal position is anteversion.

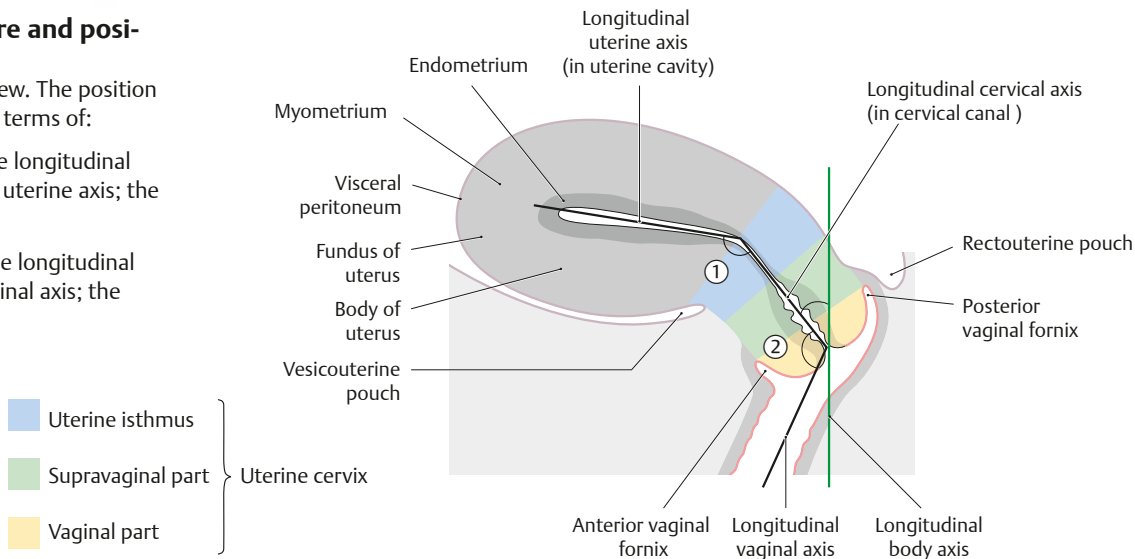
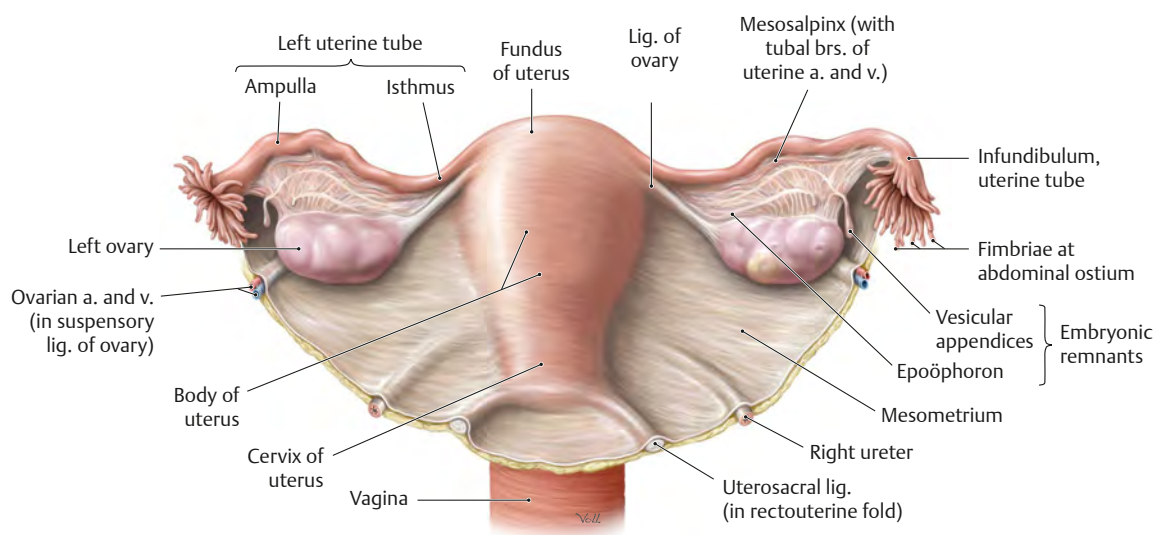
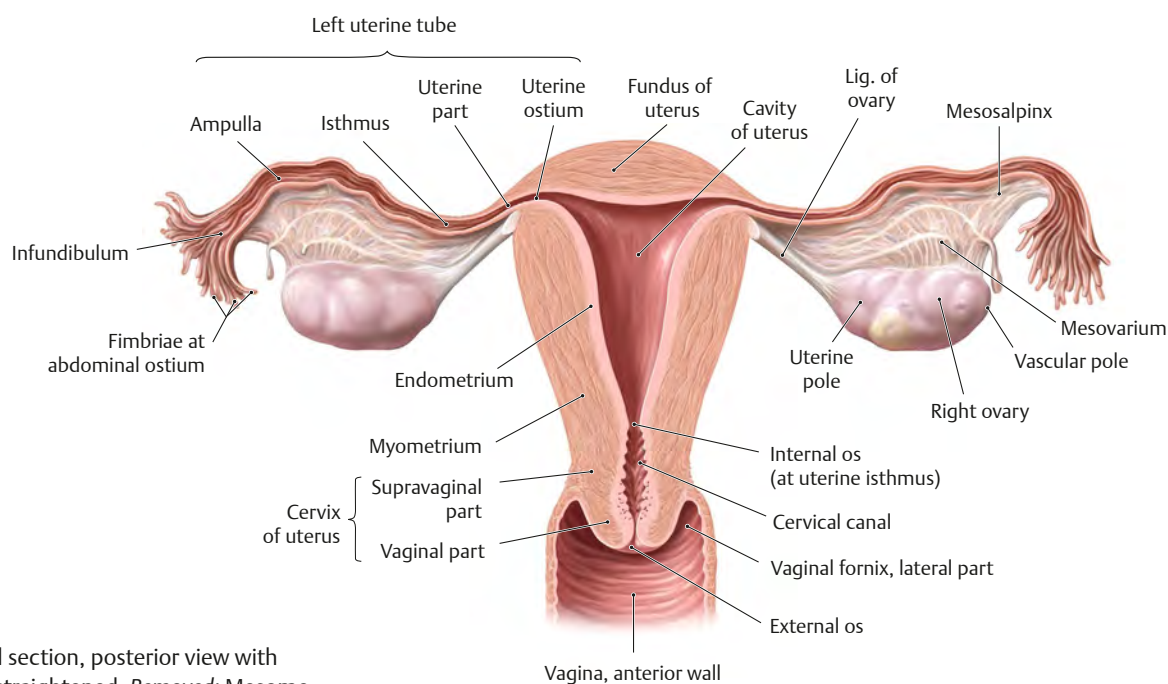


Fig. 21.17 Uterus and uterine tube**A** Posterosuperior view.**B** Coronal section, posterior view with uterus straightened. *Removed: Mesometrium.***Clinical box 21.2****Ectopic pregnancy**

After fertilization in the ampulla of the uterine tube, the ovum usually implants in the wall of the uterine cavity. However, it may become implanted at other sites (e.g., the uterine tube or even the peritoneal cavity). Tubal pregnancies, the most common type of ectopic pregnancy, pose the risk

of tubal wall rupture and potentially life-threatening bleeding into the peritoneal cavity. Tubal pregnancies are promoted by adhesion of the tubal mucosa, mostly due to inflammation.

Ligaments & Fascia of the Deep Pelvis

Fig. 21.18 Ligaments of the female pelvis

Superior view. *Removed:* Peritoneum, neurovasculature, and superior portion of the bladder to demonstrate only the fascial condensations (ligaments). Deep pelvic ligaments support the uterus within the pelvic cavity and prevent uterine prolapse, the downward displacement of the uterus into the vagina.

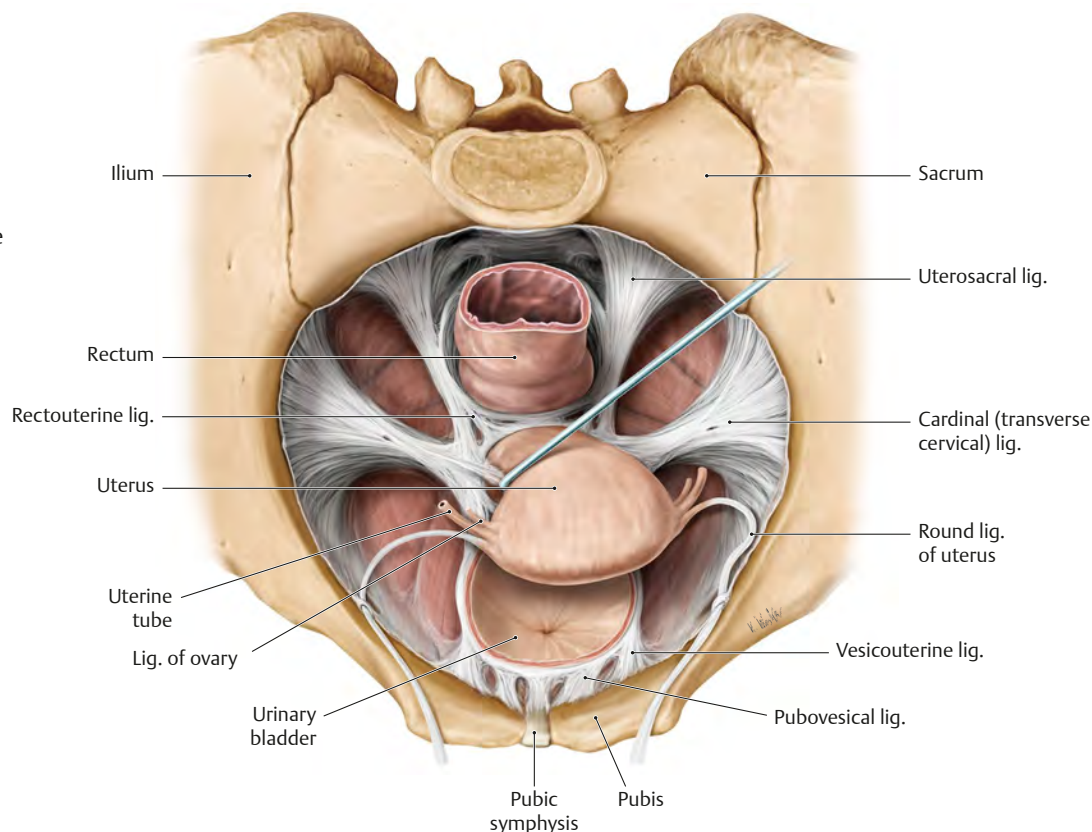
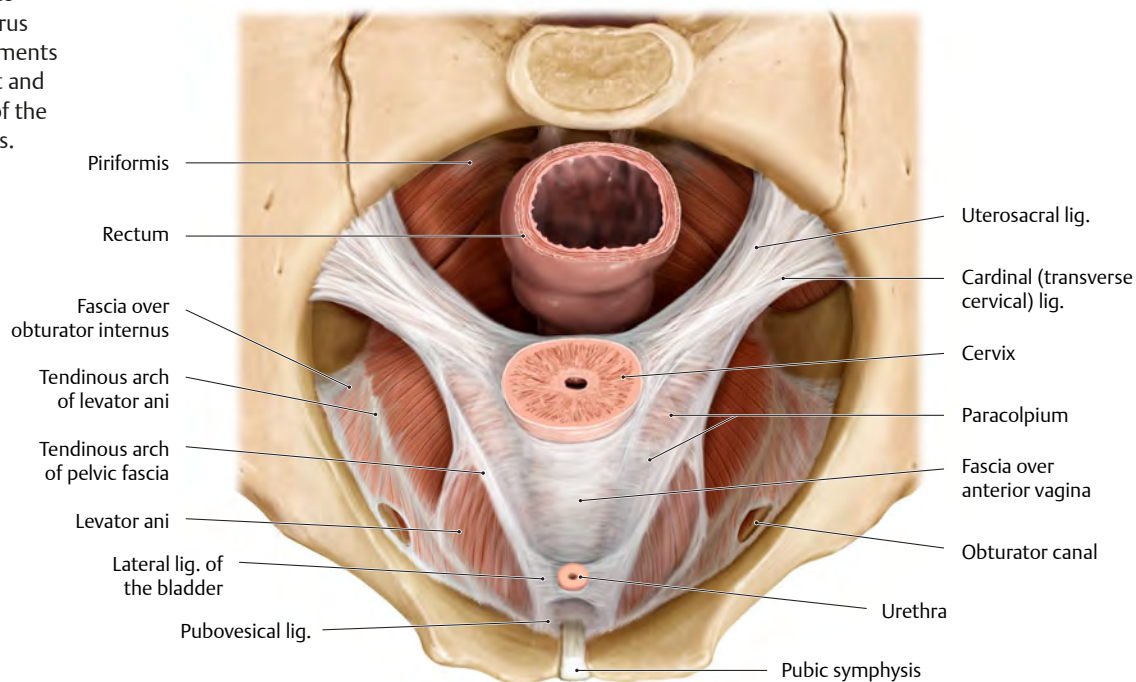


Fig. 21.19 Ligaments of the deep pelvis in the female

Superior view. *Removed:* peritoneum, neurovasculature, uterus and bladder. Uterosacral ligaments and the paracolpium support and help maintain the positions of the cervix and vagina in the pelvis.

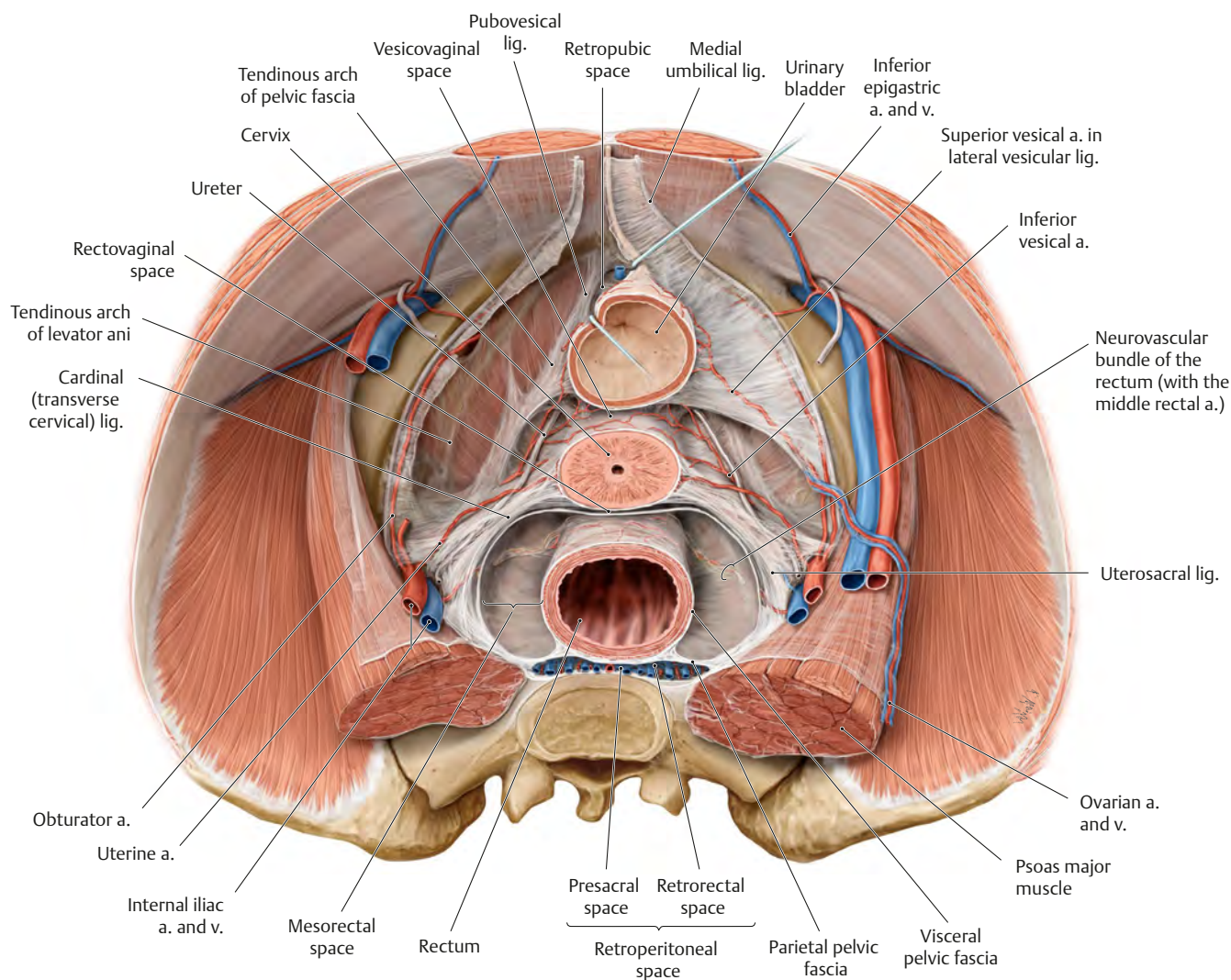


Fascia of the pelvis plays an important role in the support of pelvic viscera. On either side of the pelvic floor, where the visceral fascia of the pelvic organs is continuous with the parietal fascia of the muscular walls, thickenings called tendinous arches of the pelvic fascia are formed. In females, the paracolpium—lateral connections between the visceral fascia and the tendinous arches—suspends and supports the vagina. Pubovesical ligaments (and puboprostic ligaments in the male)

are extensions of the tendinous arches that support the bladder and prostate. Endopelvic fascia, a loose areolar (fatty) tissue that fills the spaces between pelvic viscera, condenses to form “ligaments” (cardinal, lateral visceral, and lateral rectal ligaments; see **Fig. 21.20**) that provide passage for the ureters and neurovascular elements within the pelvis.

Fig. 21.20 Fascia and ligaments of the female pelvis

Transverse section, through cervix, superior view.



Vagina

Fig. 21.21 Location of vagina
Midsagittal section, left lateral view.

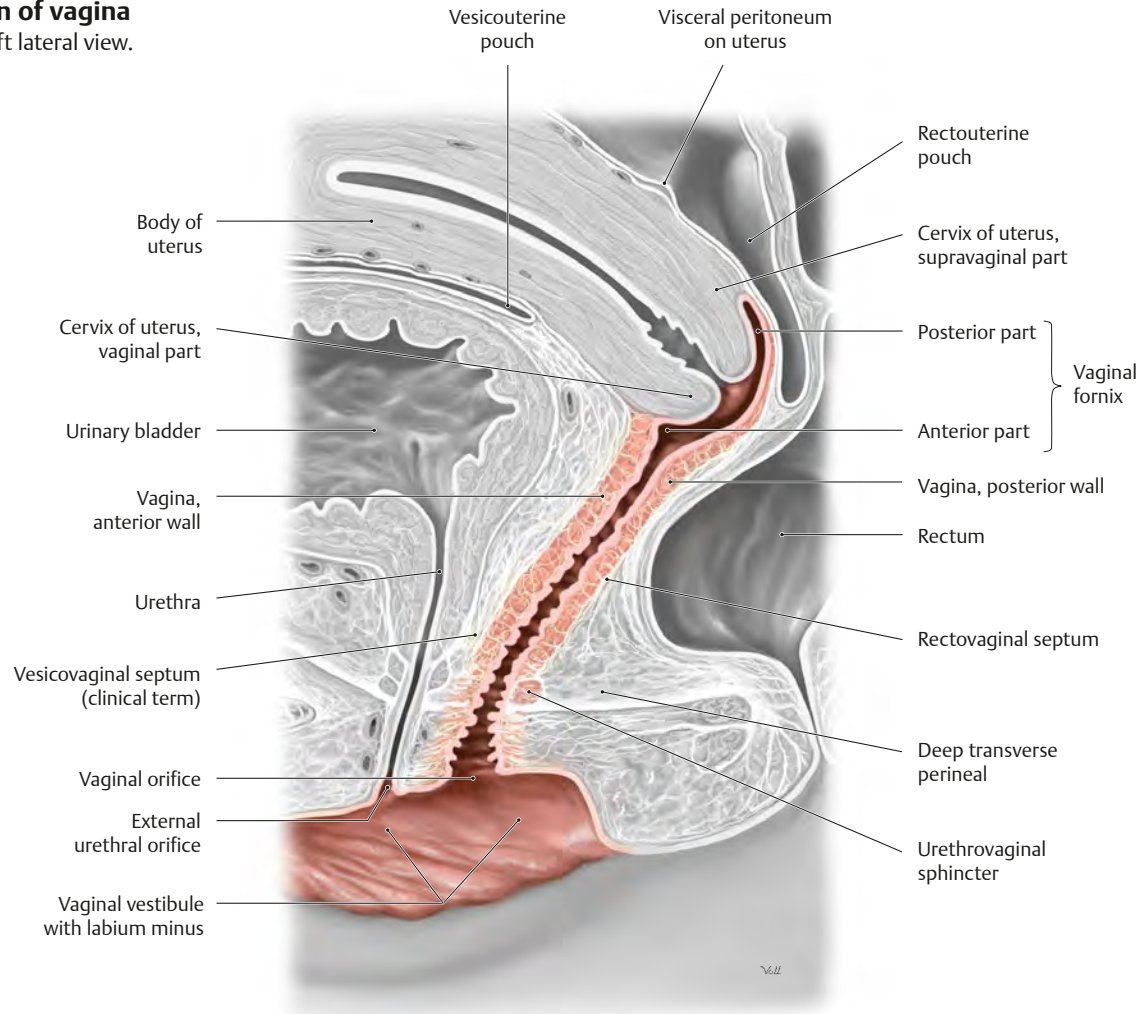


Fig 21.22 Relationship of the vagina to the peritoneum and pelvic organs
Midsagittal section, left lateral view. The vagina lies almost completely in the subperitoneal space. However, drainage of peritoneal fluid or pus from an abscess in the rectouterine space, a procedure known as culdocentesis, can be achieved through an incision in the posterior fornix.

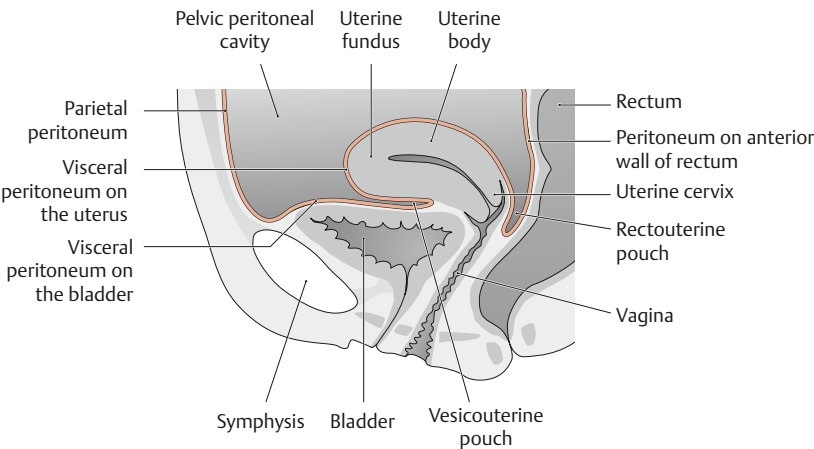


Fig. 21.23 Structure of vagina
Posteriorly angled coronal section, posterior view.

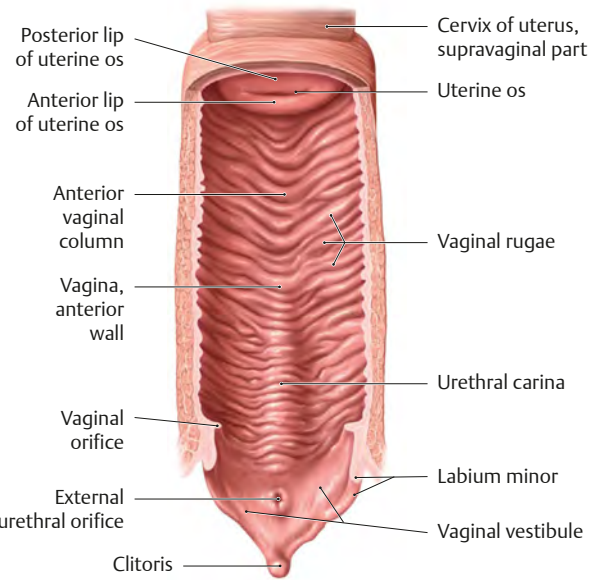
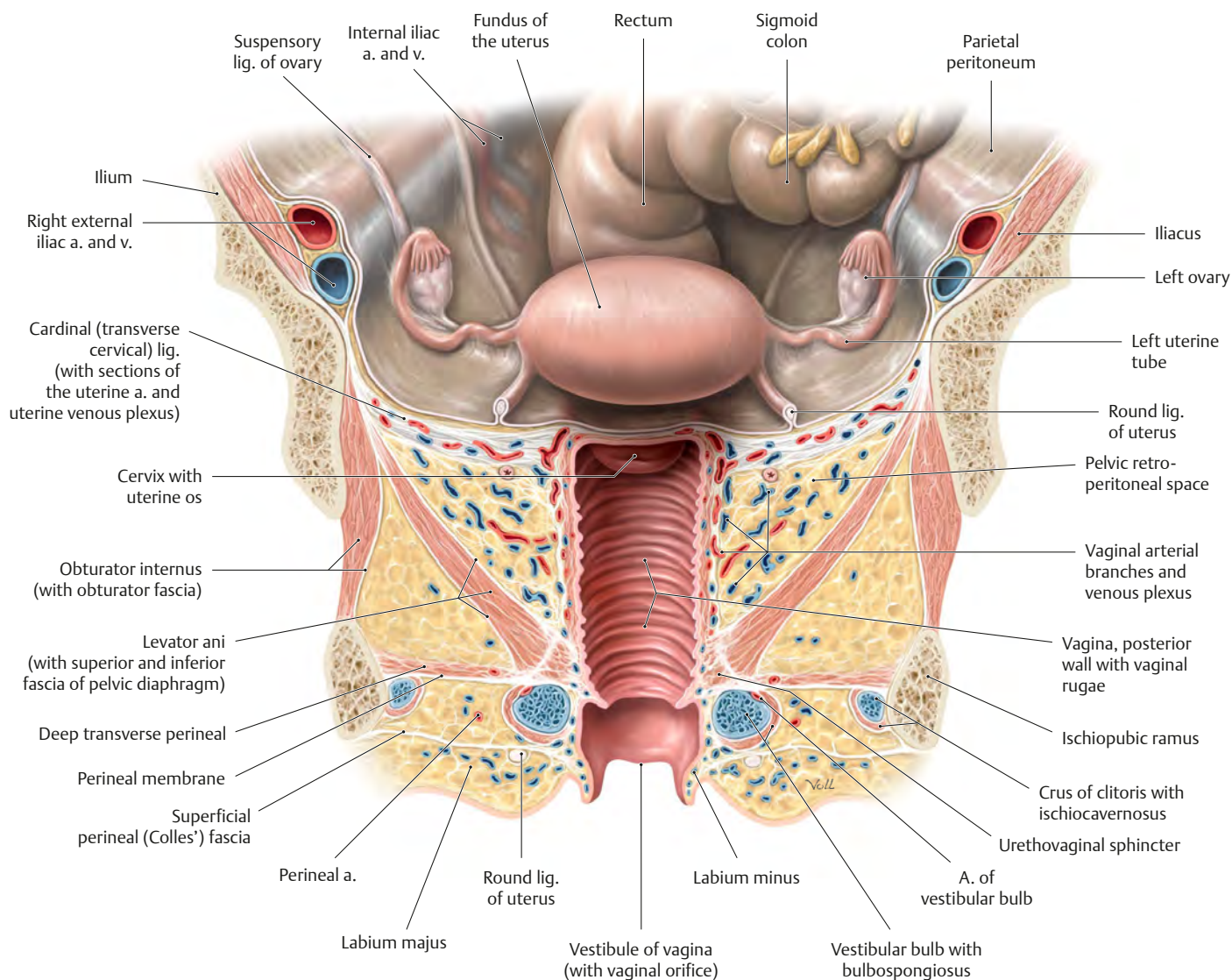
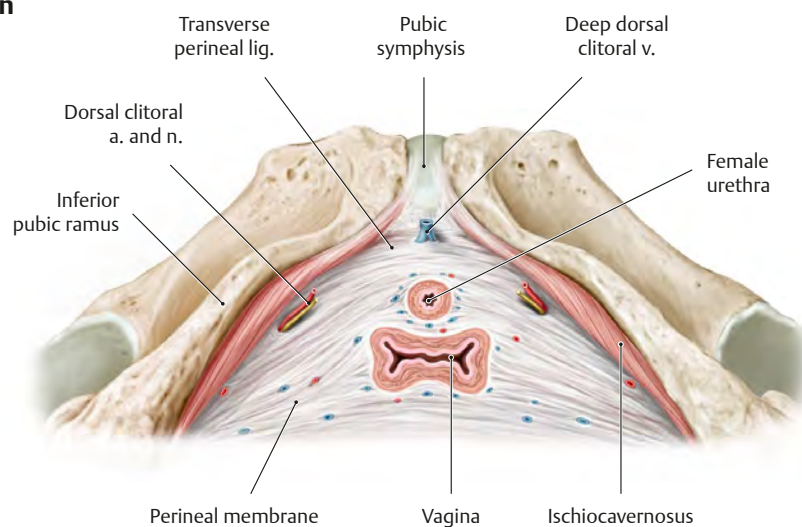


Fig. 21.24 Female genital organs: Coronal section

Anterior view. The vagina is both pelvic and perineal in location. It is also retroperitoneal.

**Fig. 21.25 Vagina: Location in the perineum**

Inferior view.



Female External Genitalia

Fig. 21.26 Female external genitalia
Lithotomy position with labia minora separated.

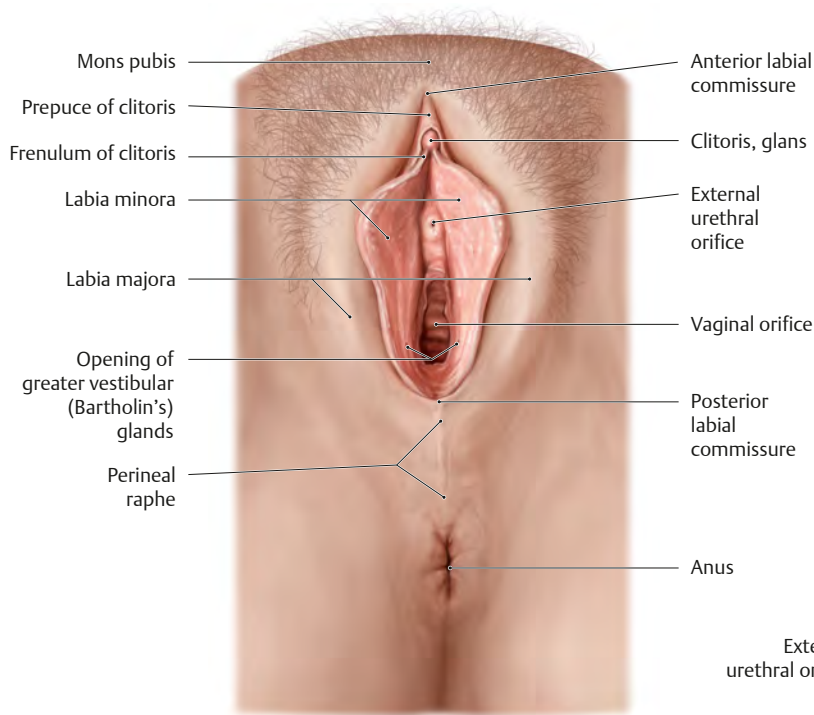


Fig. 21.27 Vestibule and vestibular glands
Lithotomy position with labia minora separated.

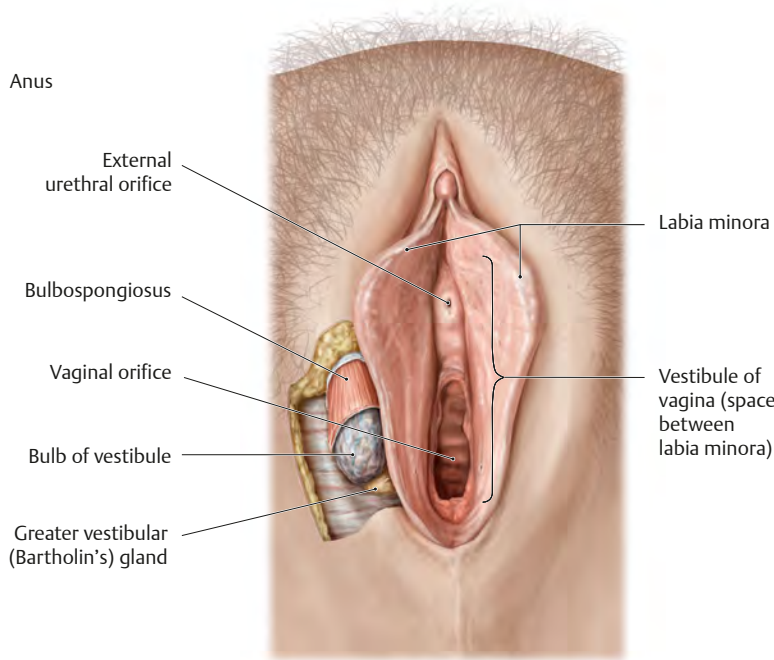


Fig. 21.28 Erectile tissue in the female perineum

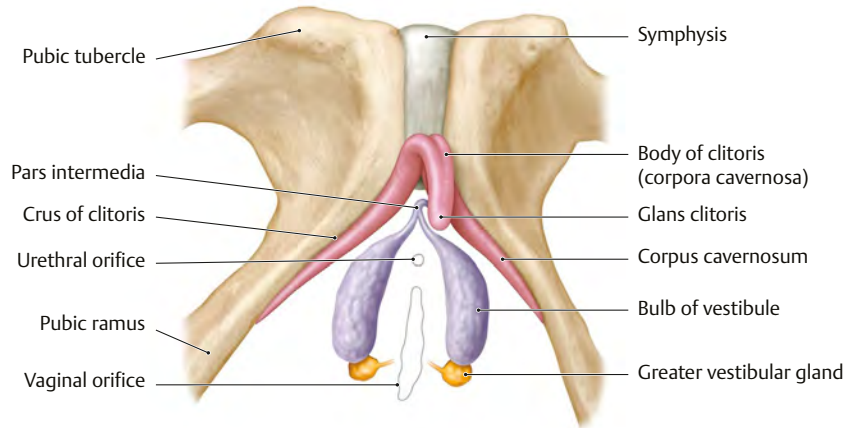
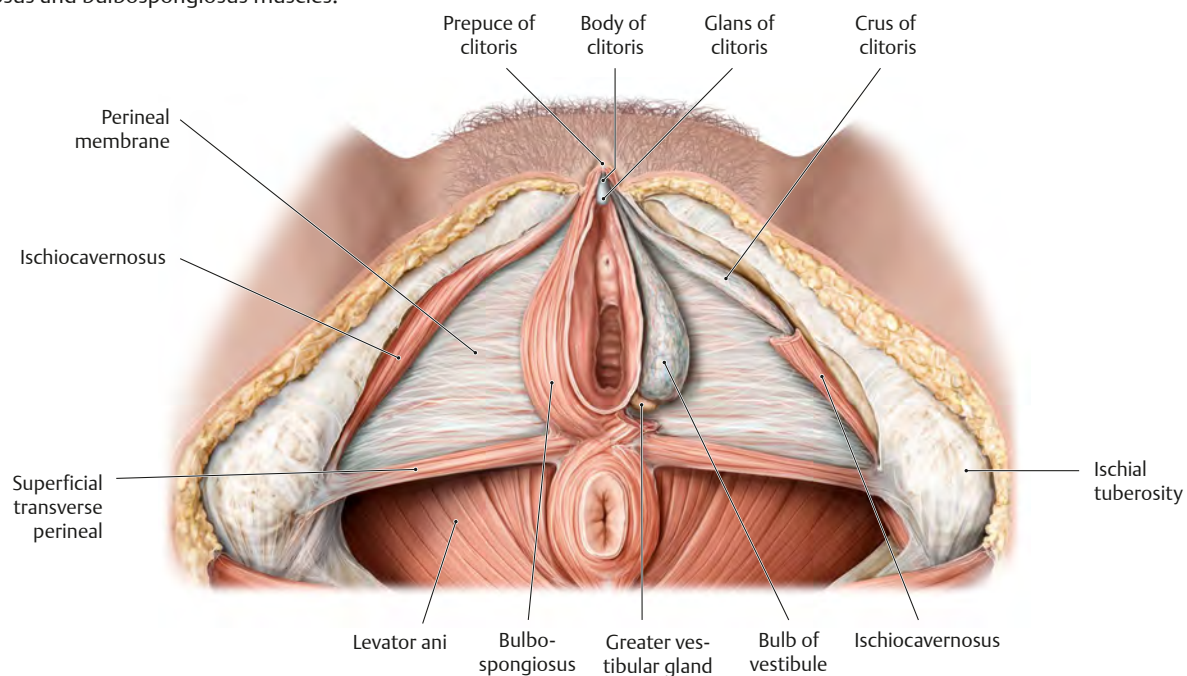


Fig. 21.29 Erectile tissue and muscles of the female

Lithotomy position. *Removed:* Labia and skin. *Removed from left side:* Ischiocavernosus and bulbospongiosus muscles.

**Clinical box 21.3****Episiotomy**

Episiotomy is a common obstetric procedure used to enlarge the birth canal during the expulsive stage of labor. The procedure is generally used to expedite the delivery of a baby at risk for hypoxia during the expulsive stage. Alternately, if the perineal skin turns white (indicating diminished blood flow),

there is imminent danger of perineal laceration, and an episiotomy is often performed. More lateral incisions gain more room, but they are more difficult to repair.

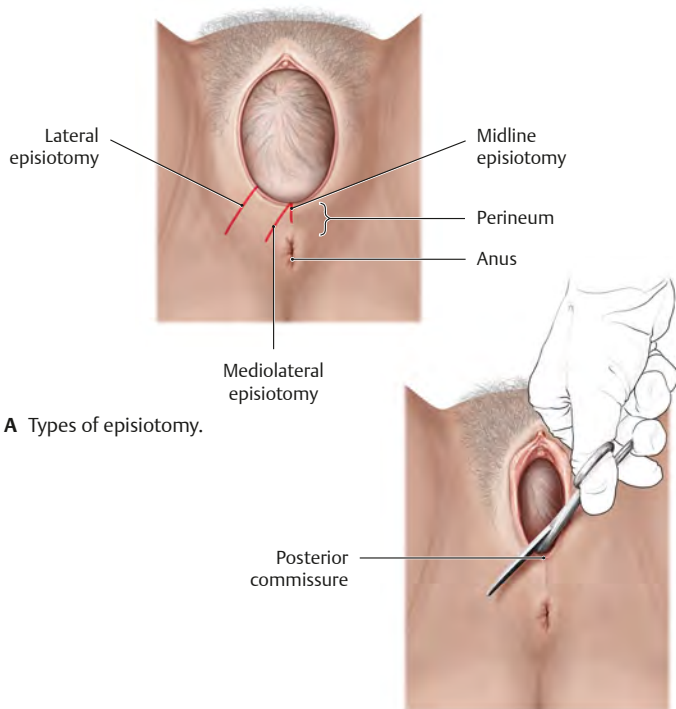
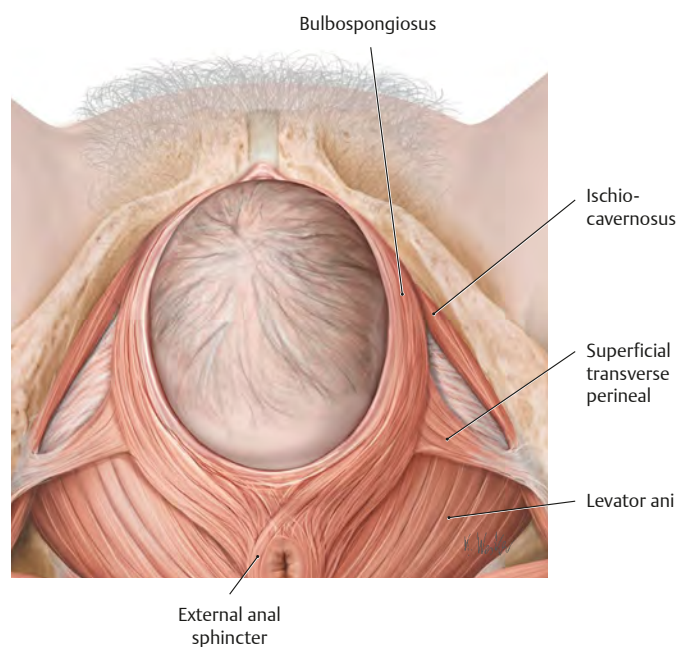
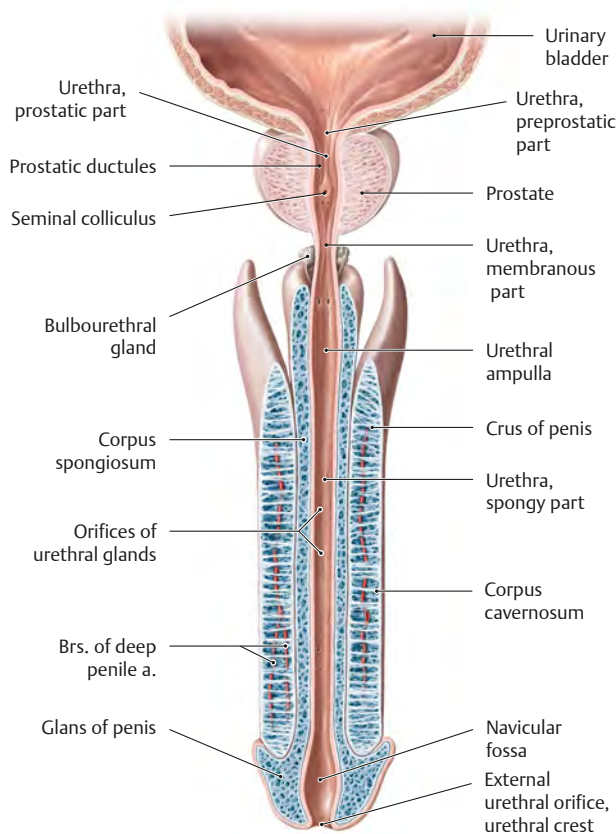
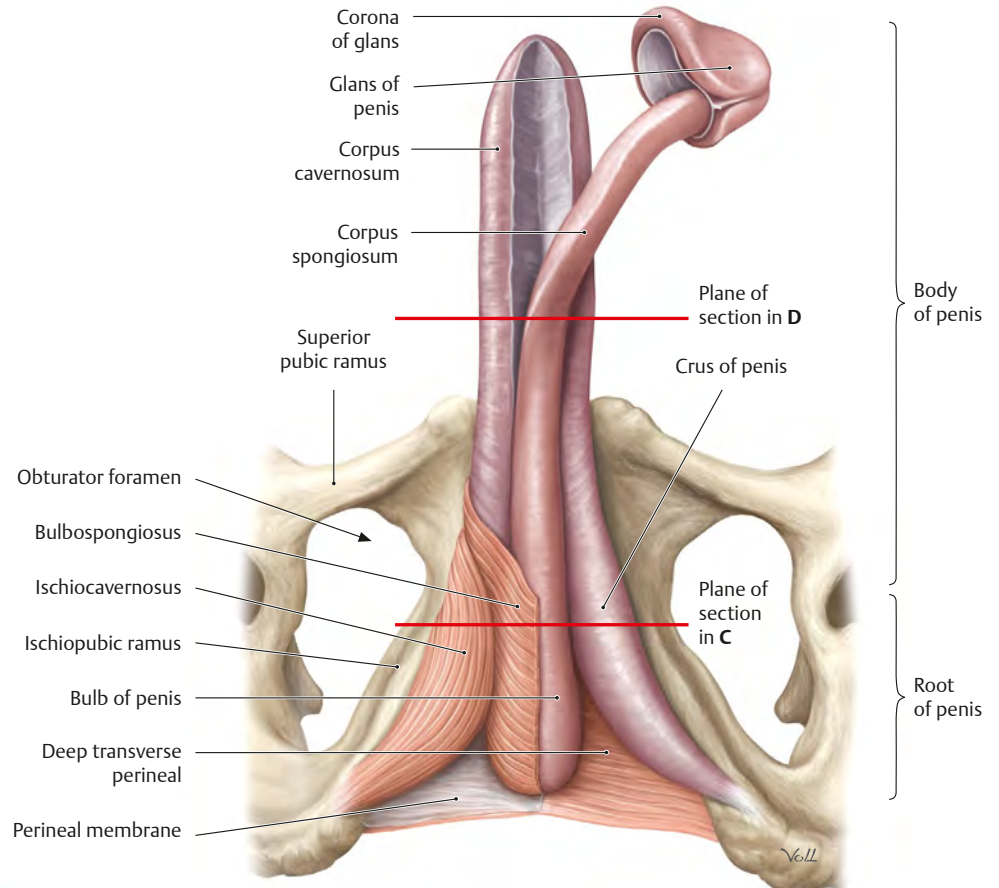
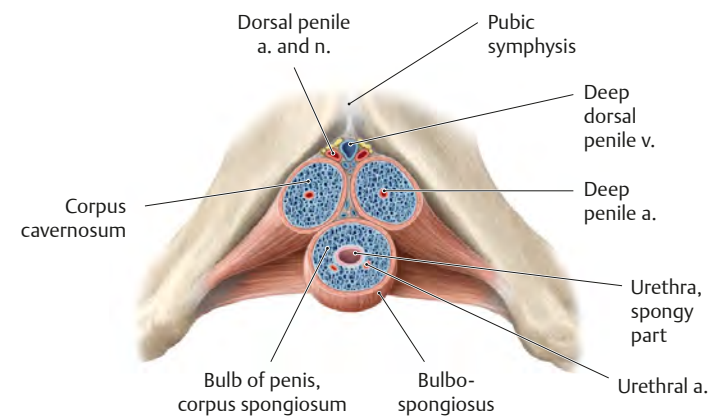
**A** Types of episiotomy.**B** Mediolateral episiotomy at height of contraction.**C** Pelvic floor with crowning of fetal head.

Fig. 21.30 Penis

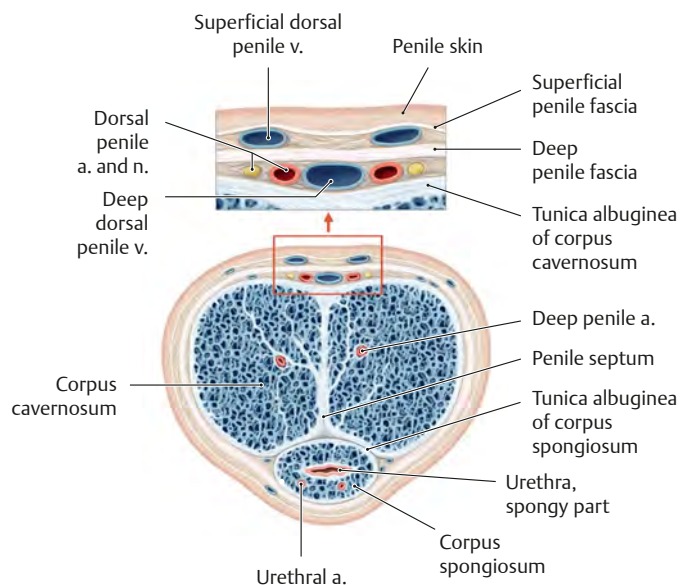
A Inferior view.



B Longitudinal section.



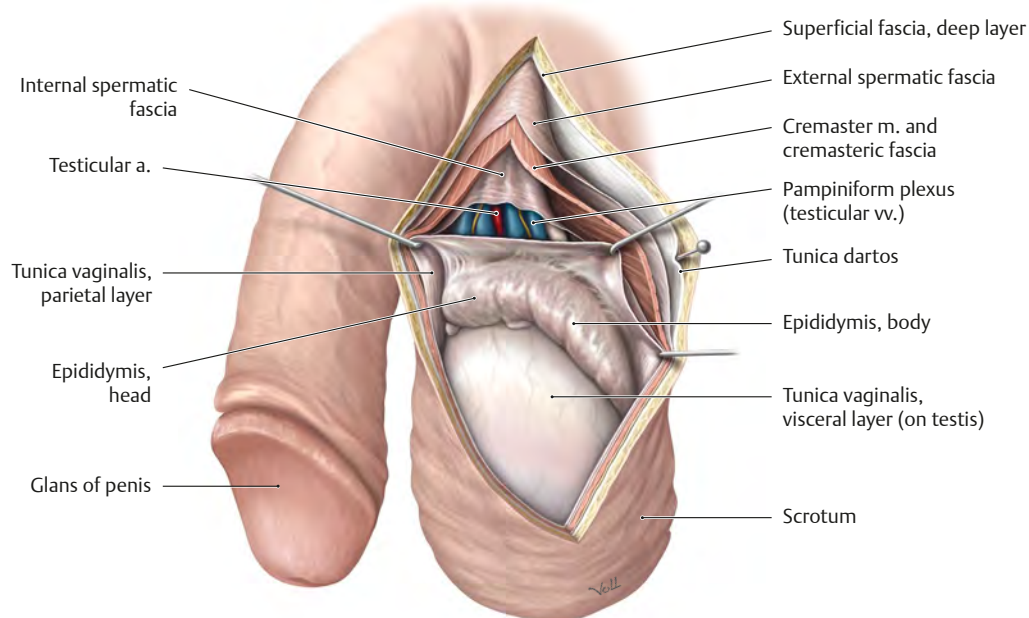
C Cross section through the root of the penis.



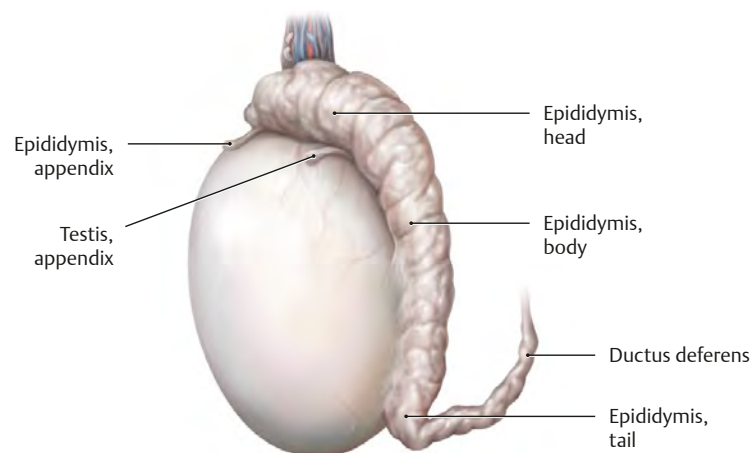
D Cross section through the body of the penis.

Fig. 21.31 Testis and epididymis

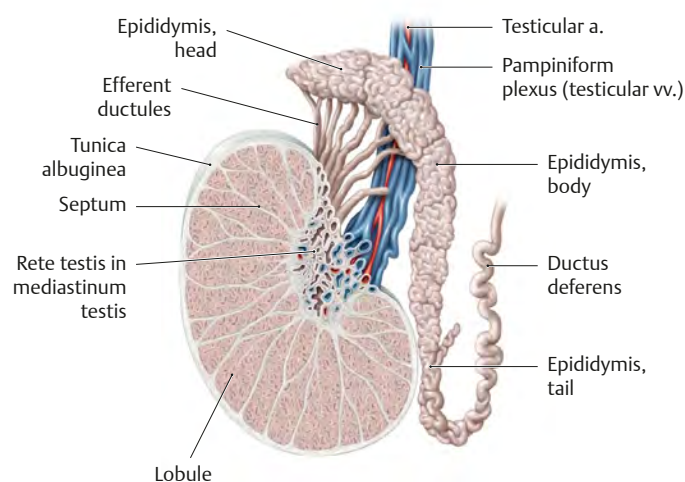
Left lateral view.



A Testis and epididymis in situ.



B Surface anatomy of the testis and epididymis.



C Sagittal section of the testis and epididymis.

Male Accessory Sex Glands

The accessory male sex glands consist of the seminal, prostate, and bulbourethral glands, which contribute fluid to the ejaculate that

provides nourishment for the spermatozoa as well as neutralizes the pH of the male urethra and the vaginal environment.

Fig. 21.32 Accessory sex glands

Posterior view.

The ducts of the seminal gland and ductus deferens combine to form the ejaculatory duct.

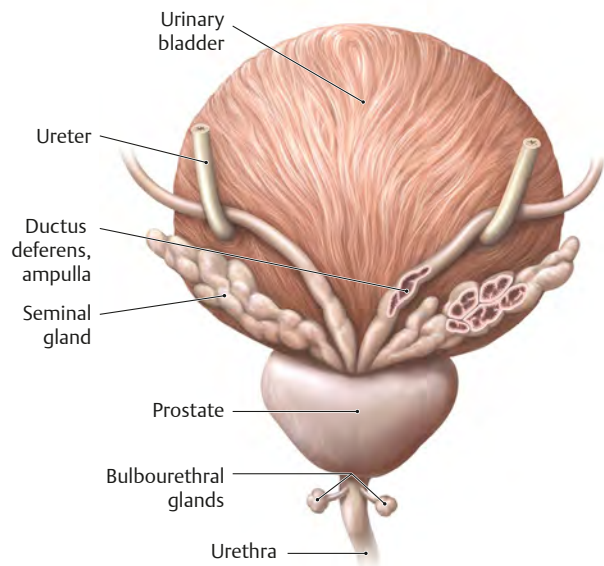
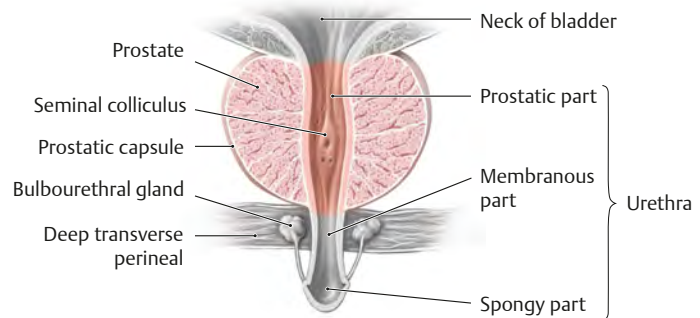


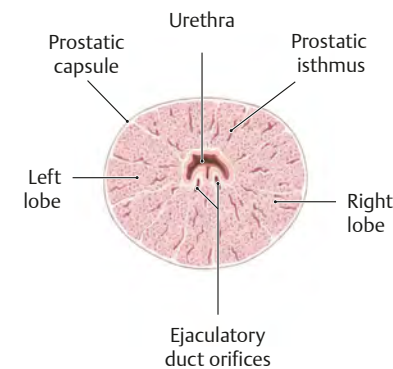
Fig. 21.33 Anatomic divisions of the prostate



A Coronal section, anterior view.

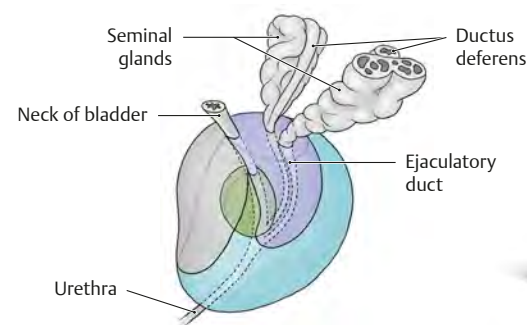


B Sagittal section, left lateral view.



C Transverse section, superior view.

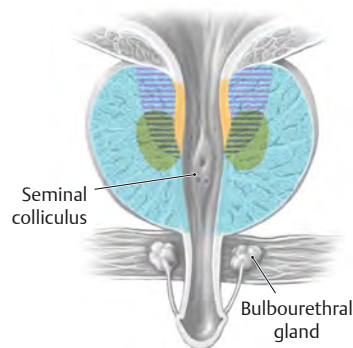
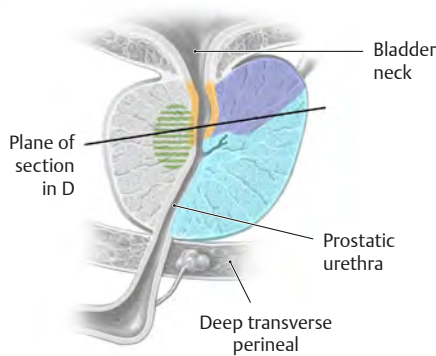
Fig. 21.34 Clinical divisions of the prostate



A Prostate and seminal glands.

- Anterior zone
- Central zone
- Peripheral zone
- Transition zone
- Periurethral zone

C Sagittal section, left lateral view.



B Coronal section, anterior view.

D Transverse section, superior view.

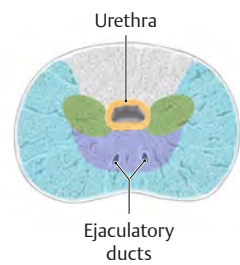
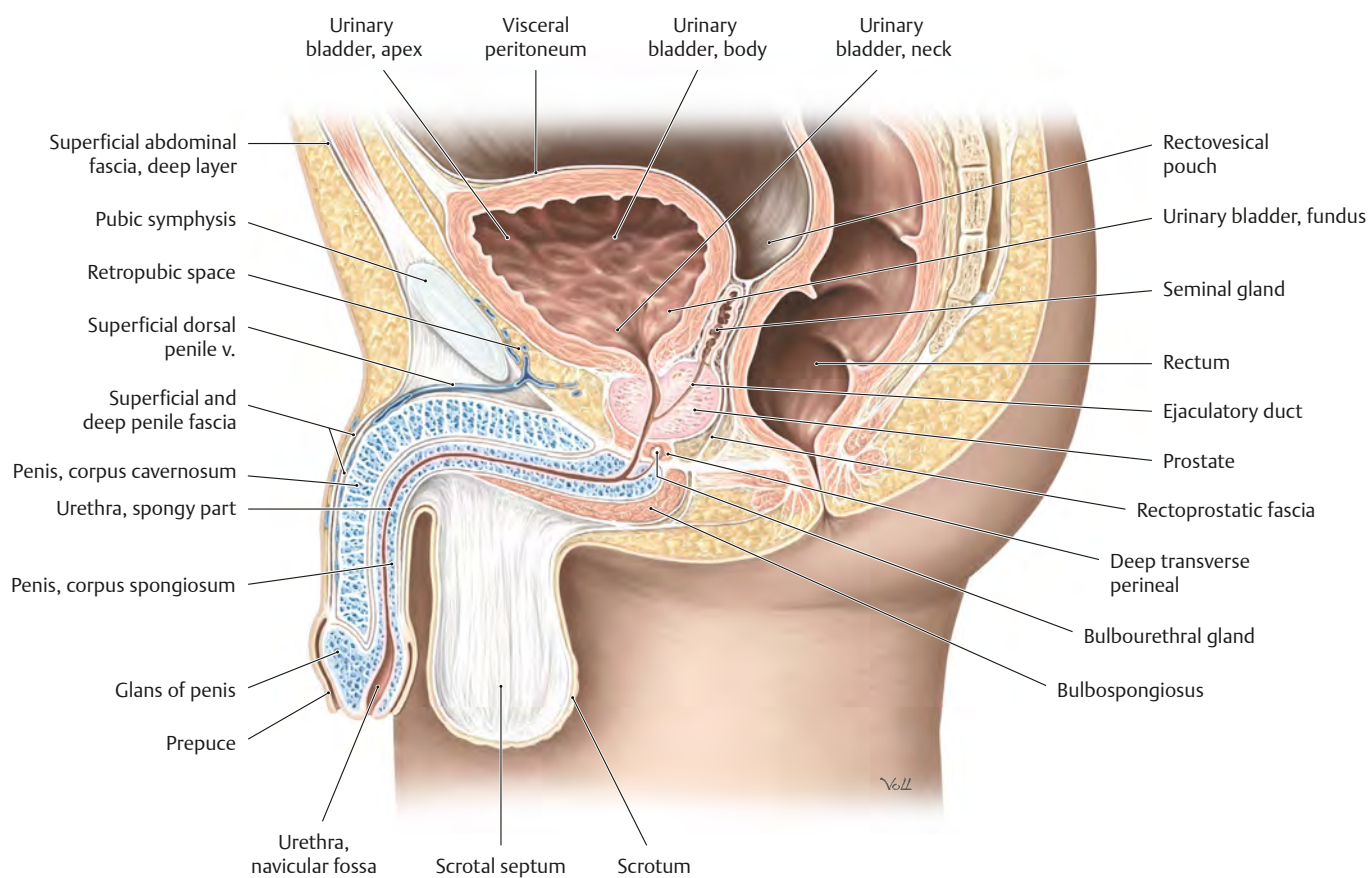


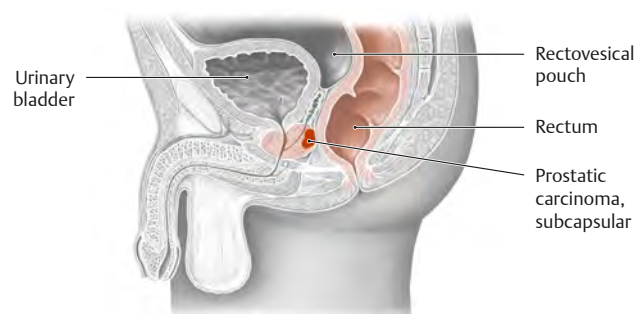
Fig. 21.35 Prostate in situ

Sagittal section through the male pelvis, left lateral view.

**Clinical box 21.4****Prostatic carcinoma and hypertrophy**

Prostatic carcinoma is one of the most common malignant tumors in older men, often growing at a subcapsular location (deep to the prostatic capsule) in the peripheral zone of the prostate. Unlike benign prostatic hyperplasia, which begins in the central part of the gland, prostatic carcinoma does not cause urinary outflow obstruction in its early stages. Being in the peripheral

zone, the tumor is palpable as a firm mass through the anterior wall of the rectum during rectal examination. In certain prostate diseases, especially cancer, increased amounts of a protein, prostate-specific antigen or PSA, appear in the blood. This protein can be measured by a simple blood test.

**A** Most common site of prostatic carcinoma.**B** Prostatic carcinoma (arrows) with bladder infiltration.

22 Neurovasculature

Overview of the Blood Supply to Pelvic Organs & Wall

Fig 22.1 Branches of the right internal iliac artery
Side wall of the male pelvis, left lateral view. The internal iliac artery arises from the common iliac artery. Its anterior trunk gives off visceral branches to pelvic organs and parietal branches to the pelvic wall. The posterior trunk gives off only parietal branches. Branches to the uterus and vagina in the female are the principal differences from the male vasculature.

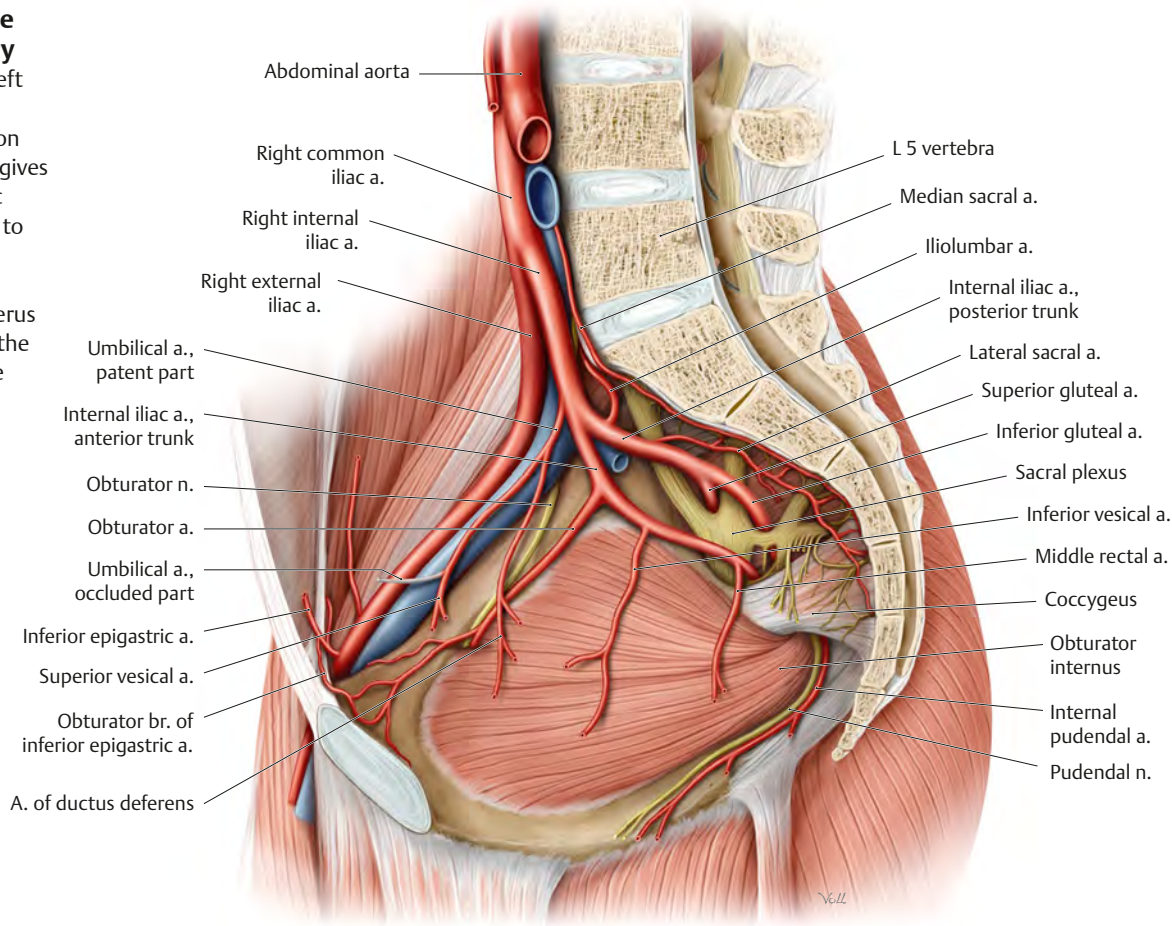
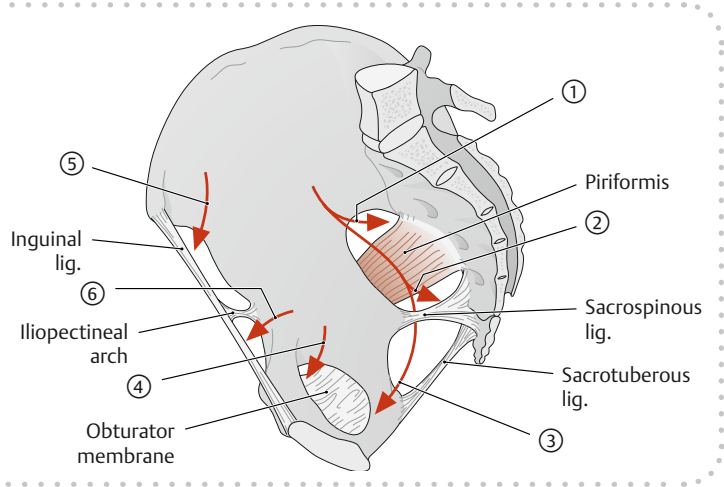
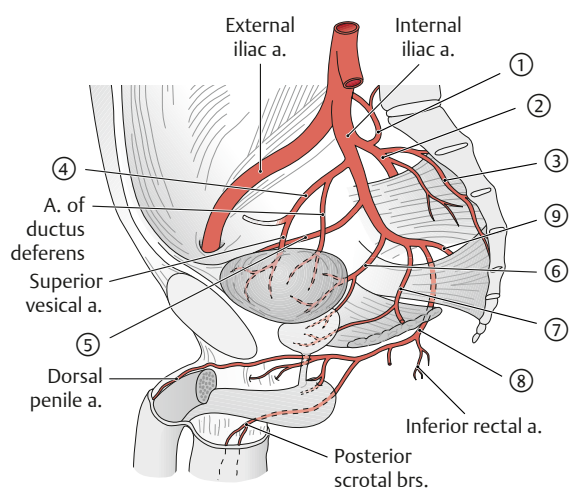
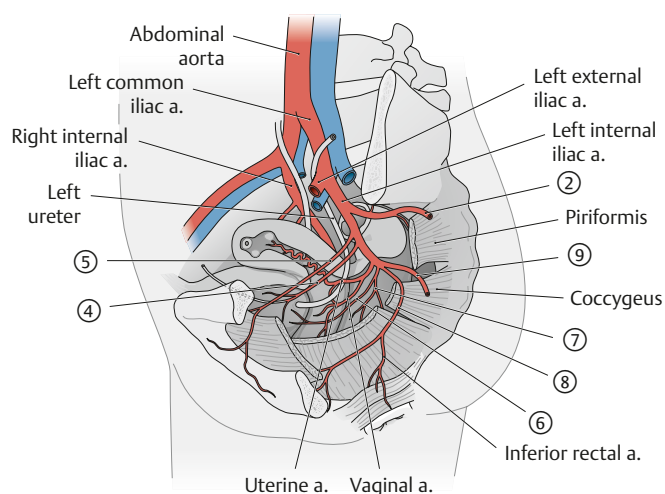


Table 22.1 Neurovascular pathways in the pelvis	
There are six major neurovascular tracts on the pelvic walls, four of which (*) contain branches from the internal iliac artery.	
Tract	Neurovascular structures transmitted
Posterior	
① Greater sciatic foramen, suprapiriform part* (above the piriformis)	Superior gluteal a. and v., superior gluteal n.
② Greater sciatic foramen, infrapiriform part* (below the piriformis)	Inferior gluteal a. and v., inferior gluteal n., sciatic n., internal pudendal a. and v., pudendal n., posterior femoral cutaneous n.
On pelvic floor	
③ Lesser sciatic foramen through pudendal canal*	Internal pudendal a. and v., pudendal n.
Lateral	
④ Obturator canal*	Obturator a. and v., obturator n.
Anterior	
⑤ Muscular lacuna (posterior to inguinal lig., lateral to iliopectineal arch)	Femoral n., lateral femoral cutaneous n.
⑥ Vascular lacuna (posterior to inguinal lig., medial to iliopectineal arch)	Femoral a. and v., lymphatic vessels (the femoral a. is a branch of the external iliac a.), femoral branch of genito-femoral n.





A Male pelvis.



B Female pelvis.

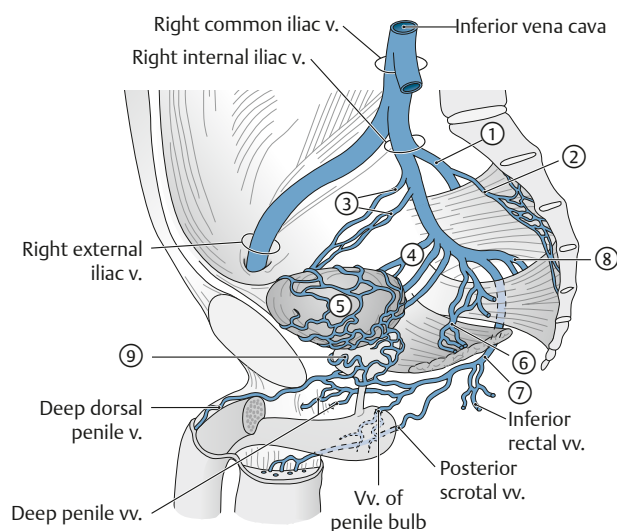
Table 22.2 Branches of the internal iliac artery

The internal iliac artery gives off five parietal (pelvic wall) and four visceral (pelvic organs) branches. * Parietal branches are shown in *italics*.

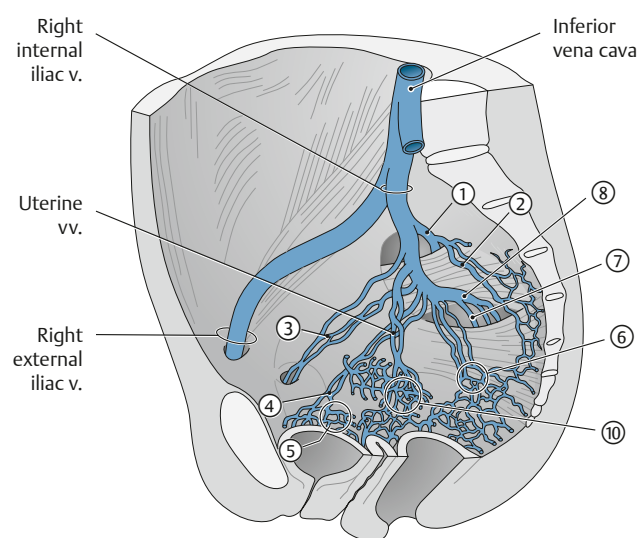
Branches

①	<i>Iliolumbar a.</i>	
②	<i>Superior gluteal a.</i>	
③	<i>Lateral sacral a.</i>	
④	Umbilical a.	A. of ductus deferens Superior vesical a.
⑤	<i>Obturator a.</i>	
⑥	Inferior vesical a.	
⑦	Middle rectal a.	
⑧	Internal pudendal a.	Inferior rectal a. Dorsal penile a. Posterior scrotal aa.
⑨	<i>Inferior gluteal a.</i>	

* In the female pelvis, the origin of the uterine and vaginal arteries is highly variable.



A Male pelvis.



B Female pelvis.

Table 22.3 Venous drainage of the pelvis

Tributaries

①	Superior gluteal v.
②	Lateral sacral v.
③	Obturator vv.
④	Vesical vv.
⑤	Vesical venous plexus
⑥	Middle rectal vv. (rectal venous plexus) (also superior and inferior rectal vv., not shown)
⑦	Internal pudendal v.
⑧	Inferior gluteal vv.
⑨	Prostatic venous plexus
⑩	Uterine and vaginal venous plexus

The male pelvis also contains veins draining the penis and scrotum.

Arteries & Veins of the Male Pelvis

Fig 22.2 Blood vessels of the male pelvis
Right hemipelvis, left lateral view.

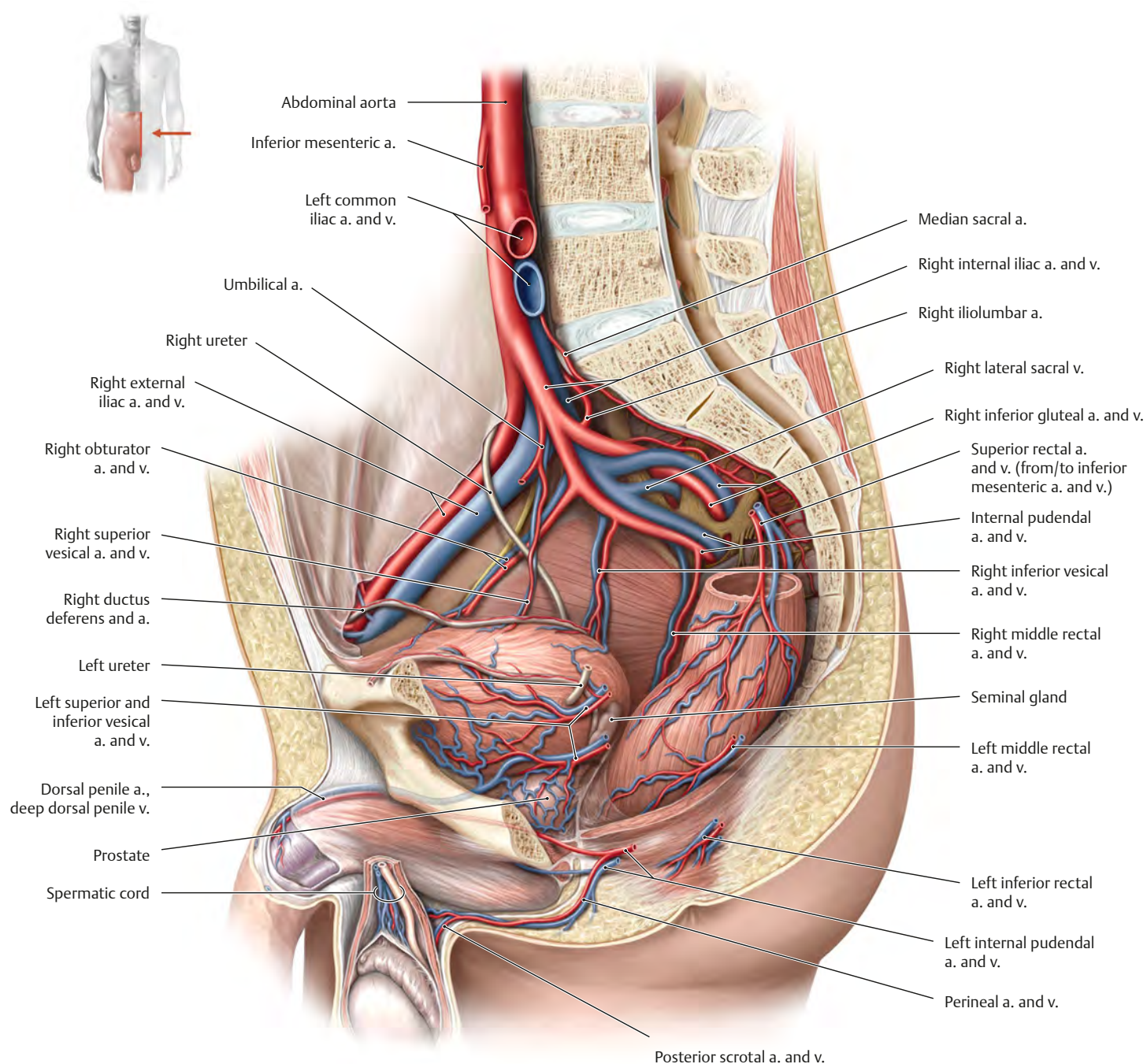
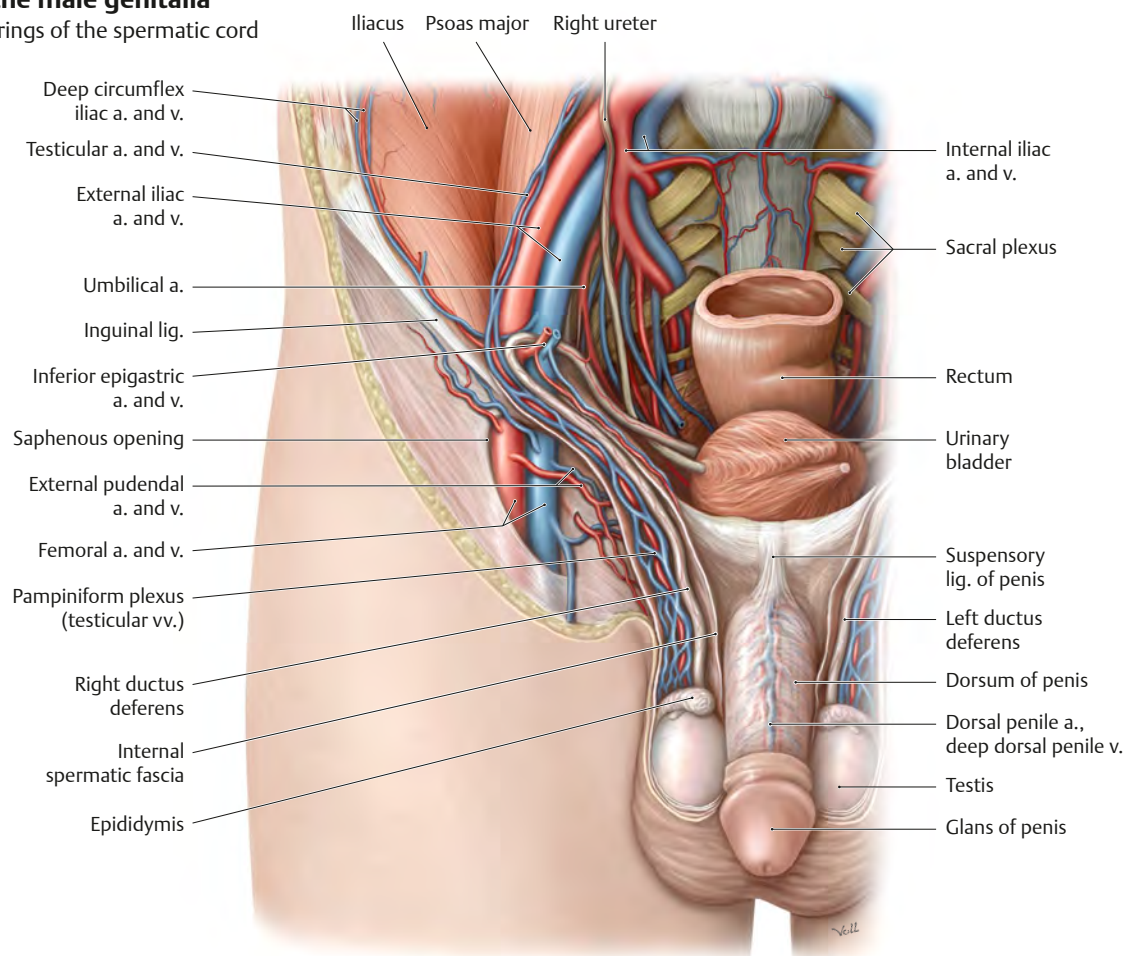
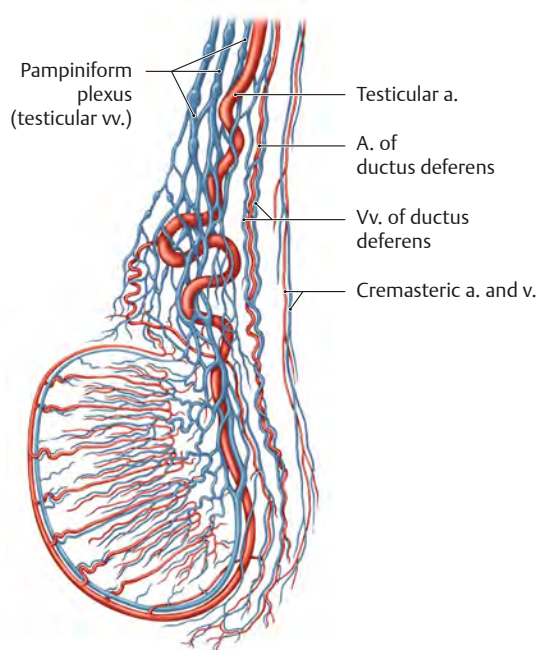


Fig 22.3 Blood vessels of the male genitalia

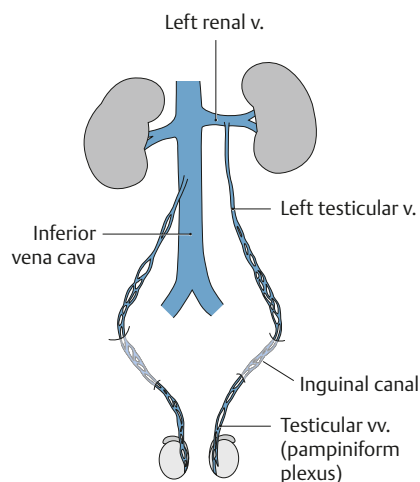
Opened: Inguinal canal and coverings of the spermatic cord

**Fig 22.4 Blood vessels of the testis**

Left lateral view.

**Clinical box 22.1****Asymmetric venous drainage of the testes**

The pampiniform plexus has an important cooling affect on the testis. Because drainage of the left testicular vein into the left renal vein is at a right angle, a physiological constriction may occur that can obstruct outflow from the testicular vein. This can result in enlargements, or “varicoceles,” of the left testicular vein and pampiniform plexus, which can disrupt the cooling function of the plexus and the fertility of the testis.



Arteries & Veins of the Female Pelvis

Fig 22.5 Blood vessels of the female pelvis
Right hemipelvis, left lateral view.

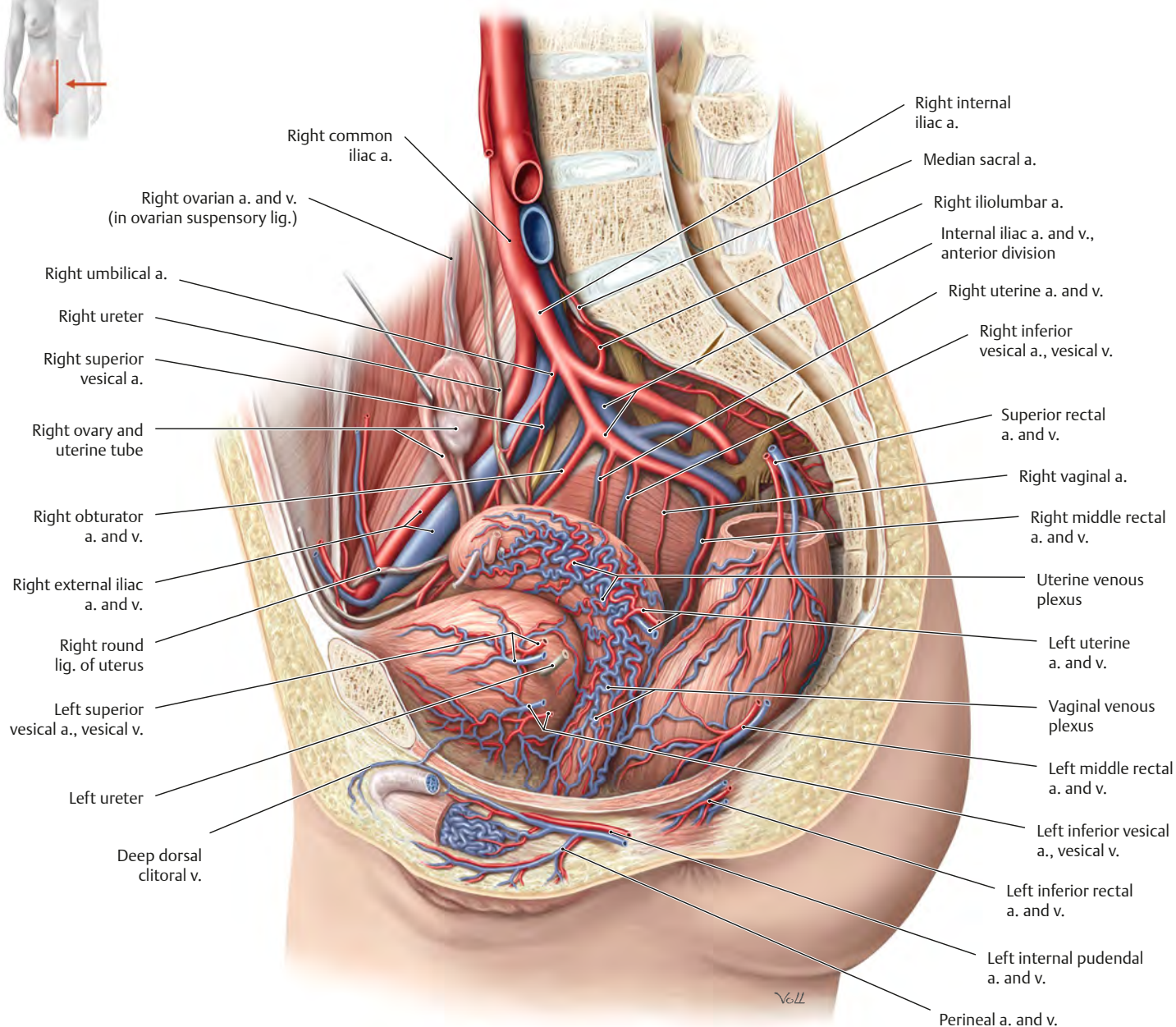
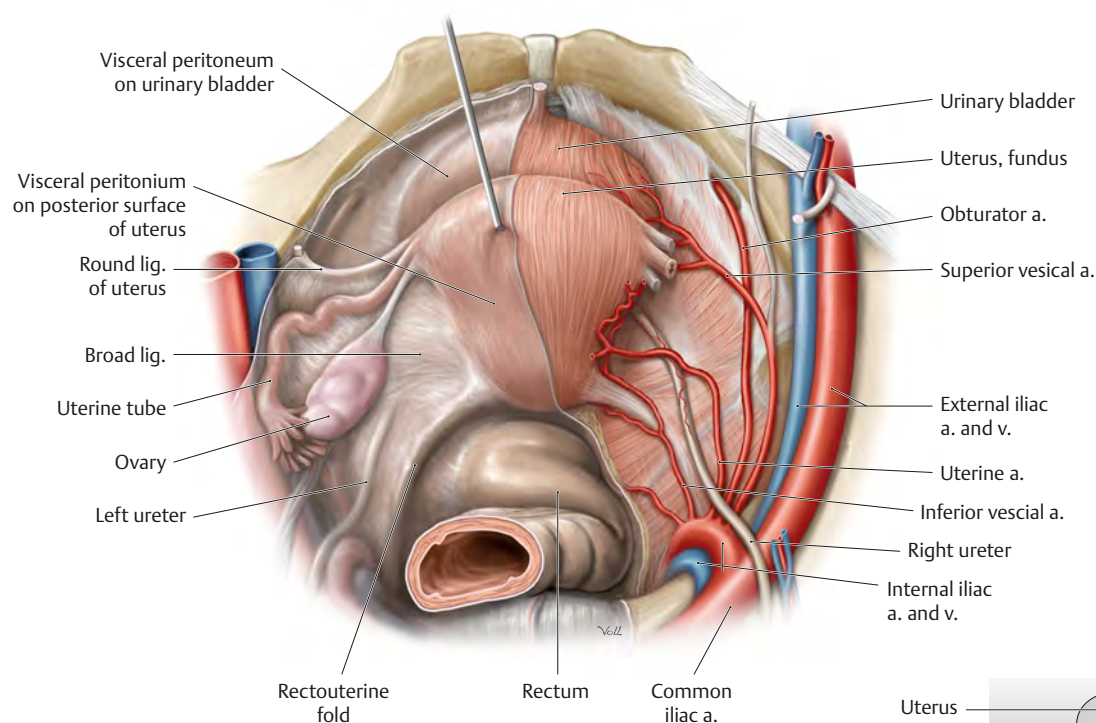
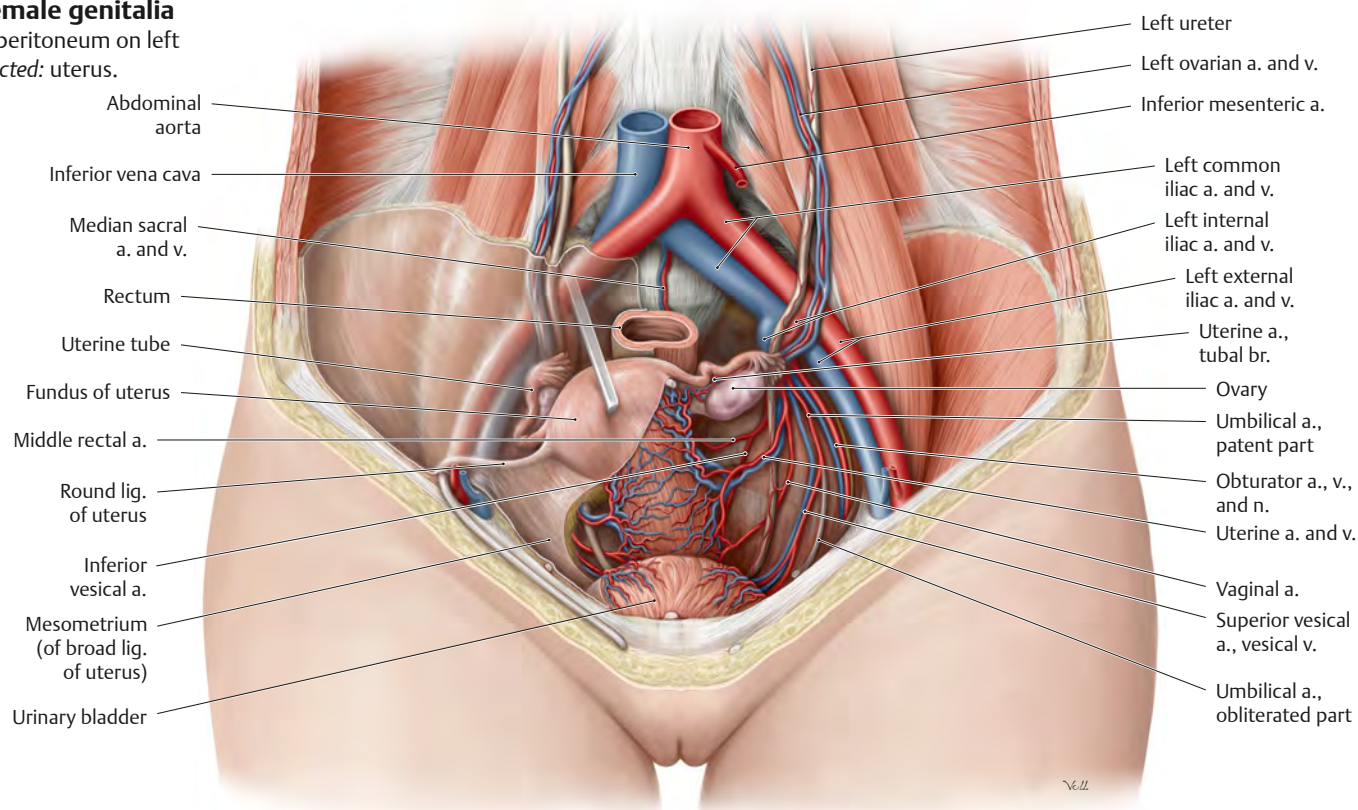


Fig 22.6 Blood vessels of the female genitalia

Removed: peritoneum on left side; Retracted: uterus.

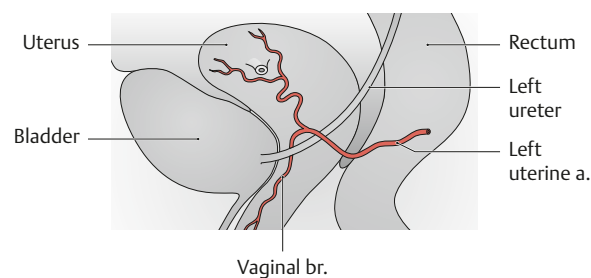


A Superior view of the pelvis.

Fig 22.7 Relationship of the uterine artery and ureter

The uterine artery runs in the broad ligament to the uterus. The ureter passes inferior to the artery lateral to the cervix. Thus the ureter is at risk for injury during uterine surgery.

B Left lateral view of left ureter and left uterine artery.



Arteries & Veins of the Rectum & External Genitalia

Fig. 22.8 Blood vessels of the rectum

Posterior view. The superior rectal arteries are the main blood supply to the rectum; the middle rectal arteries serve as an anastomosis between the superior and inferior rectal arteries. Similarly, the middle rectal

veins provide an important portocaval collateral pathway between the superior and inferior rectal veins.

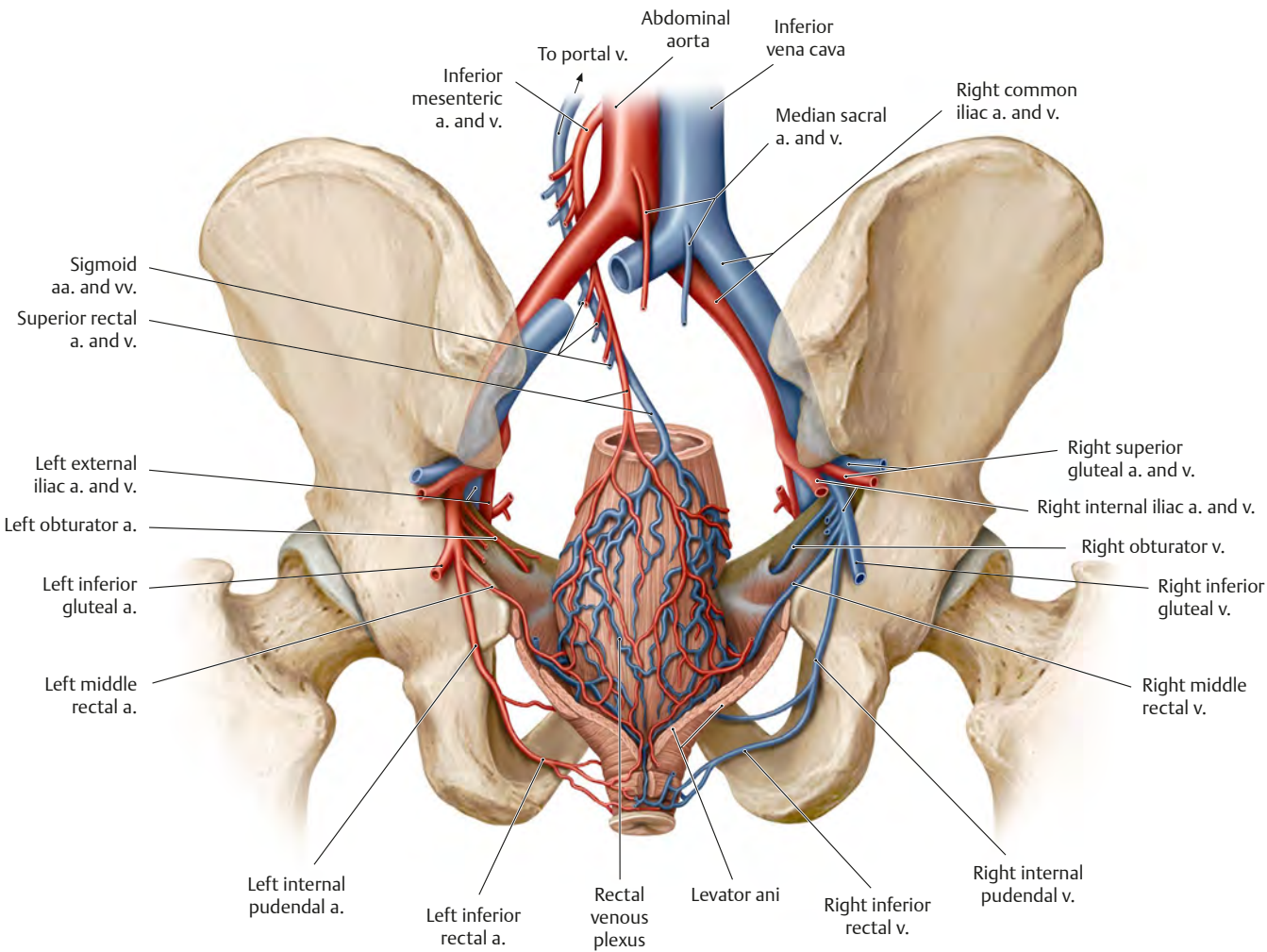


Fig. 22.9 The hemorrhoidal plexus

Longitudinal section of the anal canal with the hemorrhoidal plexus windowed. The hemorrhoidal plexus, supplied by branches of the superior rectal artery, is a permanently distended cavernous body that forms circular cushions in the area of the anal columns. When filled with blood, these cushions serve as an effective continence mechanism that ensures liquid and gas-tight closure. The sustained contraction of the muscular sphincter apparatus inhibits venous drainage, but when the sphincter relaxes during defecation, blood is allowed to drain via arteriovenous anastomoses to the inferior mesenteric vein and middle and inferior rectal veins.

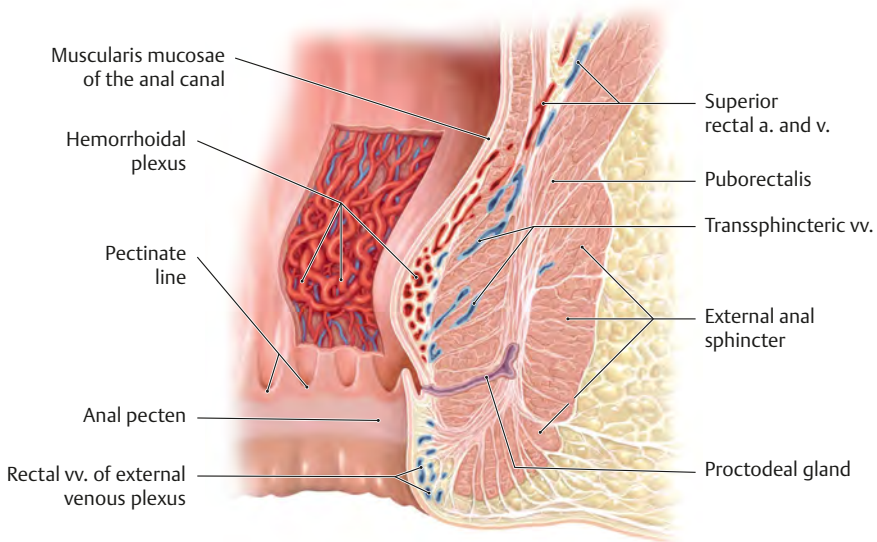
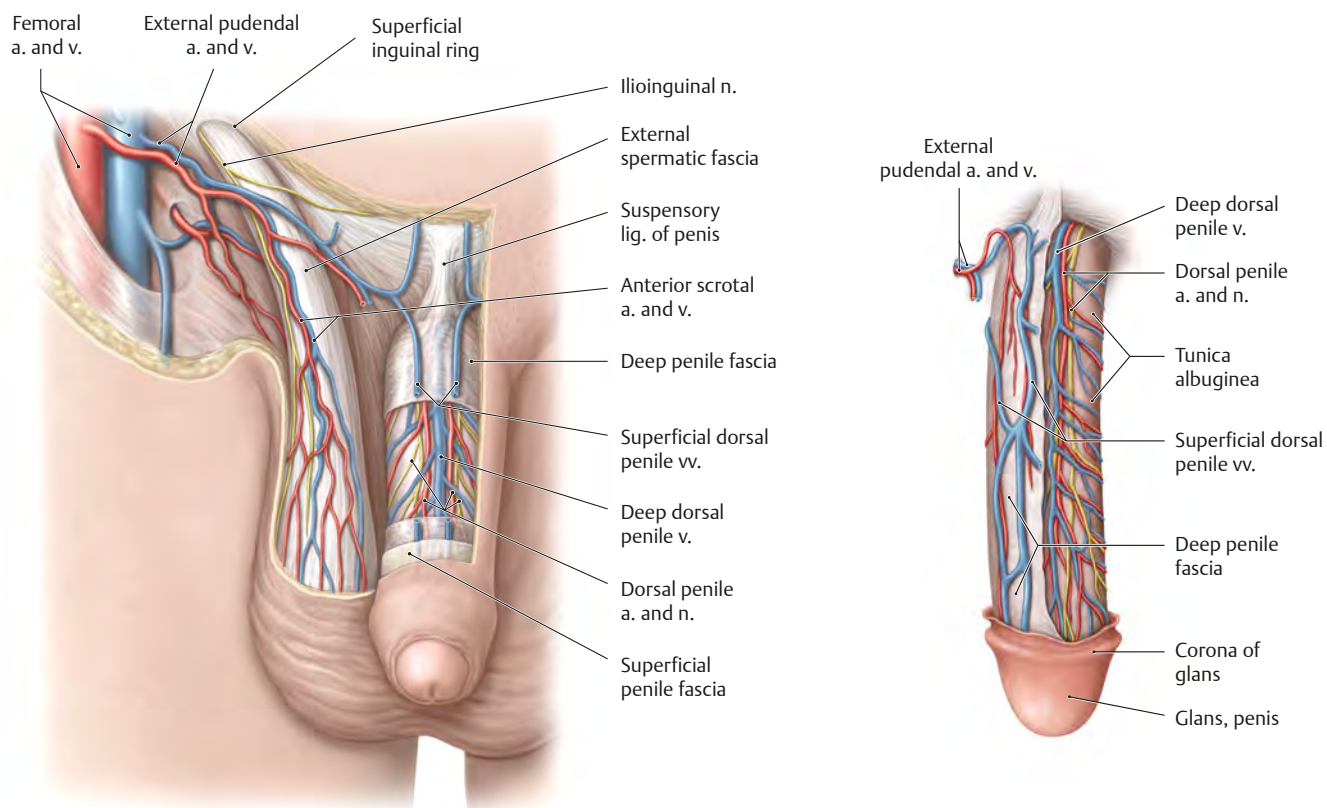
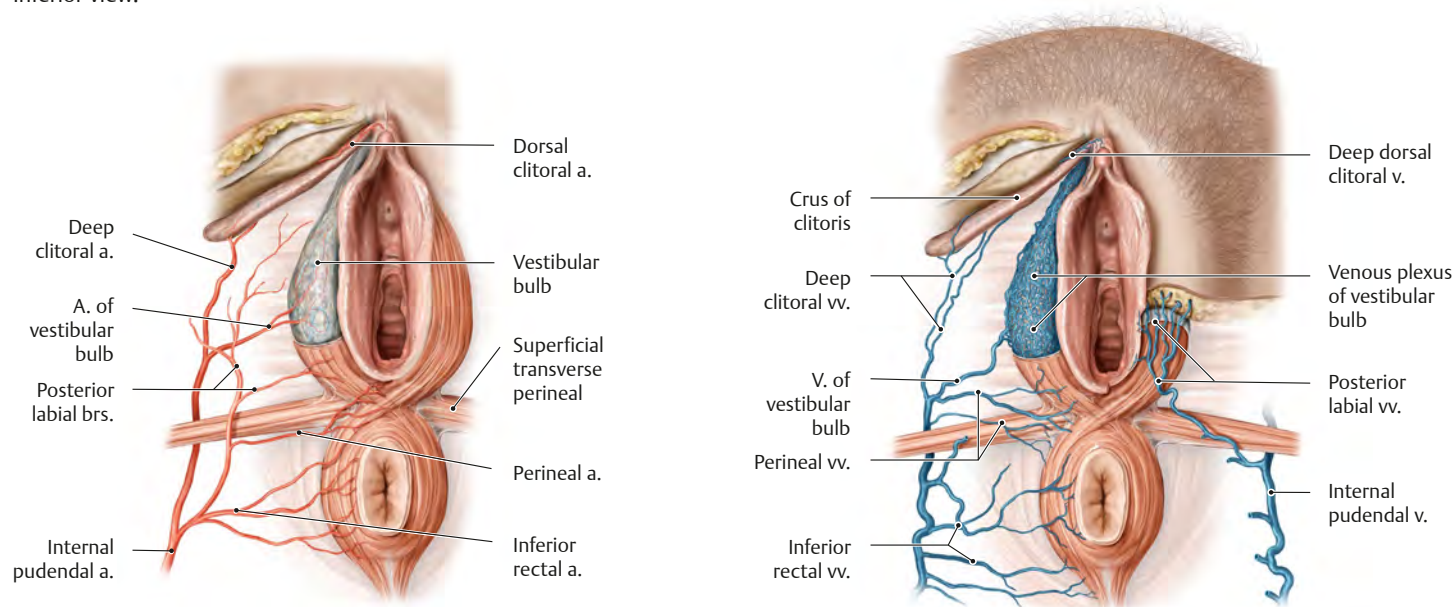


Fig. 22.10 Neurovasculature of the penis and scrotum**Fig. 22.11 Blood vessels of the female external genitalia**

Inferior view.



Lymphatics of the Pelvis

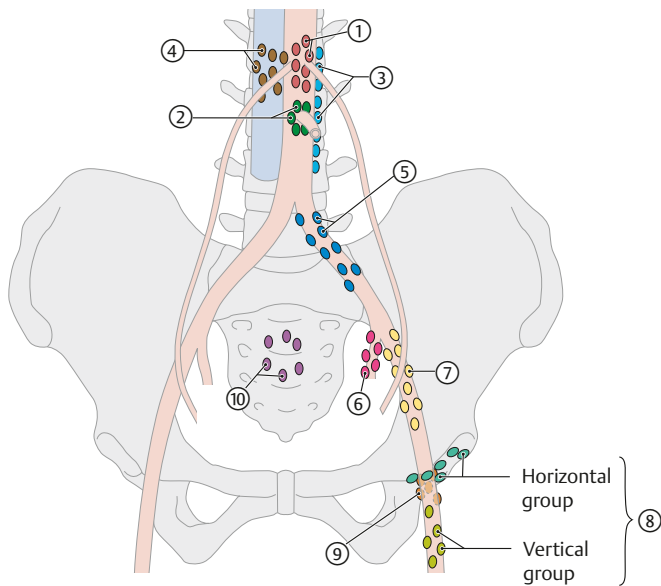


Table 22.4 Lymph nodes of the pelvis

Lymph nodes of the pelvis are distributed along major blood vessels and anterior to the sacrum. Lymph from pelvic organs can drain to one or more of several groups of lymph nodes (inguinal, internal iliac, external iliac, sacral or common iliac) before passing to the preaortic or lateral aortic nodes. Lymph from the perineum may drain first to superficial or deep inguinal nodes before draining to the external iliac nodes. Note that the testes and ovaries drain directly to lateral aortic nodes.

Preaortic l.n.	① Superior mesenteric l.n.
	② Inferior mesenteric l.n.
③ Left lateral aortic l.n.	
④ Right lateral aortic (caval) l.n.	
⑤ Common iliac l.n.	
⑥ Internal iliac l.n.	
⑦ External iliac l.n.	
⑧ Superficial inguinal l.n.	Horizontal group
	Vertical group
⑨ Deep inguinal l.n.	
⑩ Sacral l.n.	

Fig 22.12 Lymphatic drainage of the rectum

Anterior view. Three zones of the rectum drain to different groups of lymph nodes. The upper zone drains to inferior mesenteric nodes. The middle zone and columnar part of the lower zone drains to internal iliac nodes. The cutaneous part of the lower zone drains to superficial inguinal nodes.

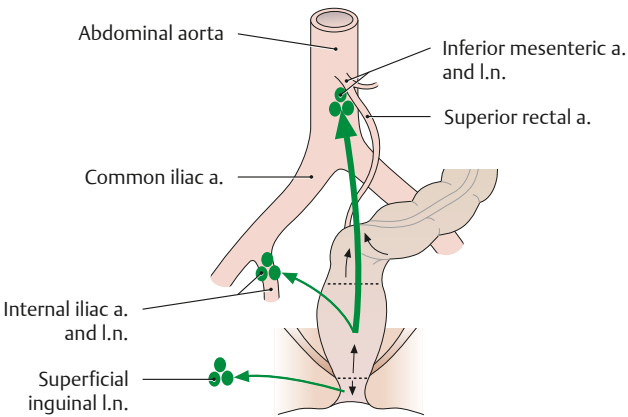


Fig 22.13 Lymphatic drainage of the bladder and urethra

Anterior view. Different parts of the bladder drain to internal iliac or external iliac nodes or directly to the common iliac nodes. The urethra, as well as the penis in the male, is drained by superficial and deep inguinal nodes.

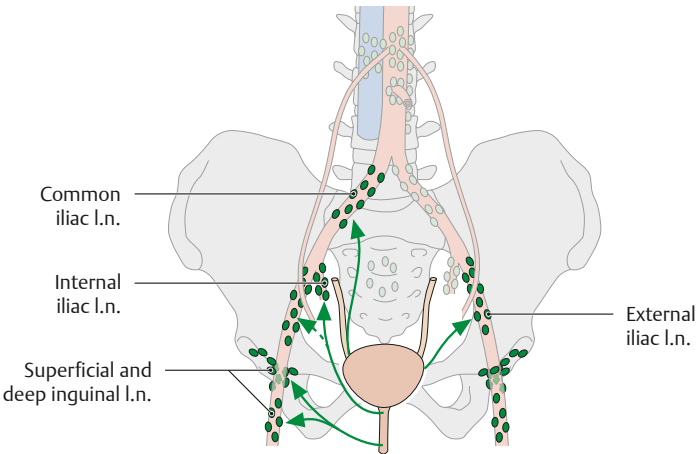
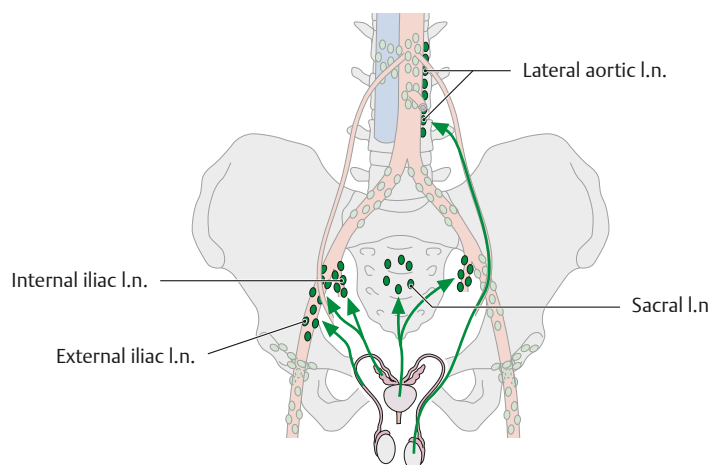


Fig 22.14 Lymphatic drainage of the male genitalia

Male pelvis, anterior view. Male genitalia drain to the lumbar lymph nodes via several pathways:

Testis and epididymis – drain via a direct pathway along the testicular vessels to the right and left lumbar lymph nodes. Some lymph from the epididymis may drain first to internal iliac nodes.

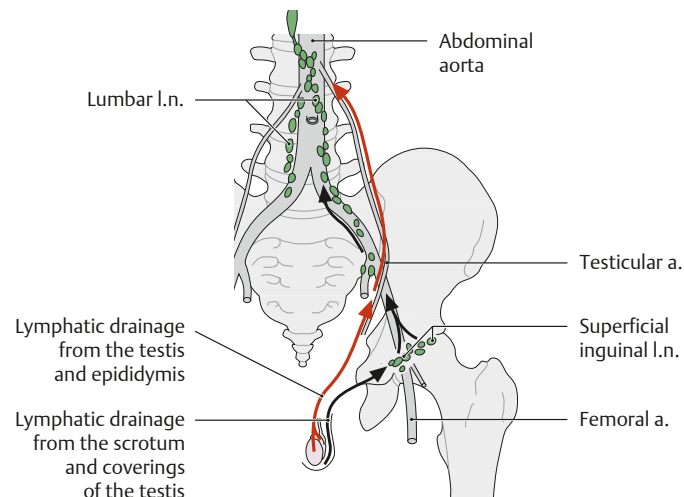
Ductus deferens and seminal glands – drain to external iliac (primarily) and internal iliac nodes.



A Lymphatic drainage of the prostate, epididymis, ductus deferens and testes.

Prostate – drain along multiple pathways including to external iliac, internal iliac, and sacral nodes

Scrotum and coverings of the testes – drain to superficial inguinal nodes



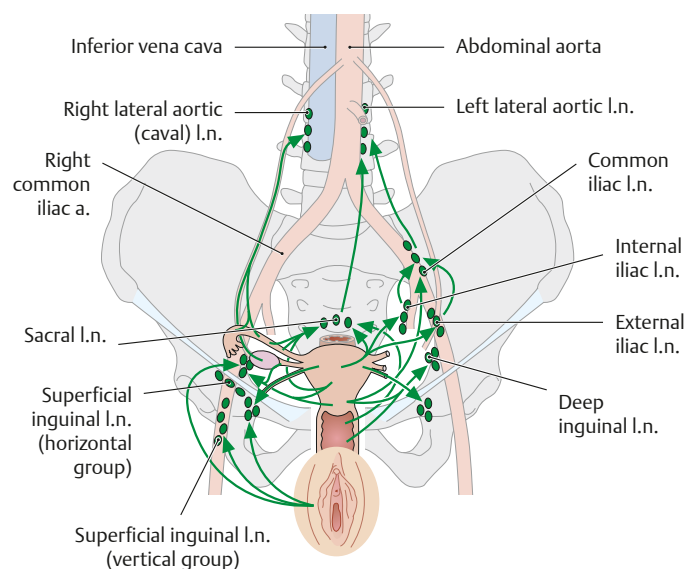
B Lymphatic drainage of the testes and scrotum.

Fig 22.15 Lymphatic drainage of the female genitalia

Female pelvis, anterior view. Female genitalia drain to the lumbar lymph nodes via several pathways:

Ovary, uterine fundus and distal part of uterine tube – drain via a direct pathway along the ovarian vessels to right and left lumbar lymph nodes.

Uterine fundus and body, and proximal part of uterine tube – drain to internal iliac, external iliac, and sacral nodes.

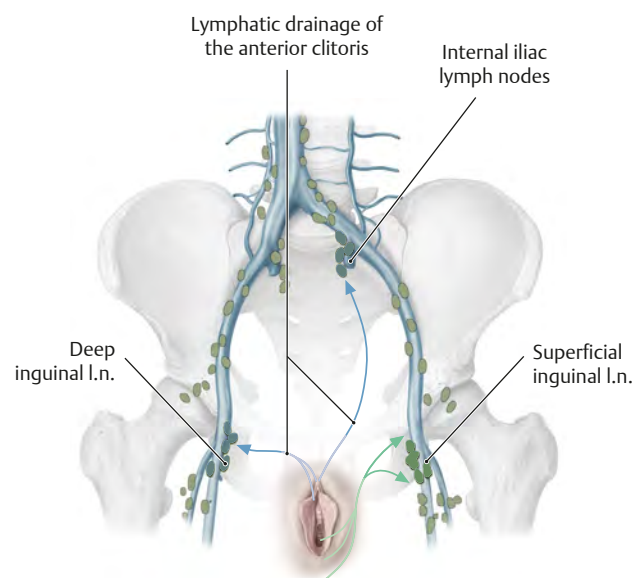


A Lymphatic drainage of the ovary, uterus, uterine tube, vagina, and labia.

Uterine cervix, middle and upper part of vagina – drain to deep inguinal nodes

External genitalia (except anterior clitoris) – drain to superficial inguinal nodes

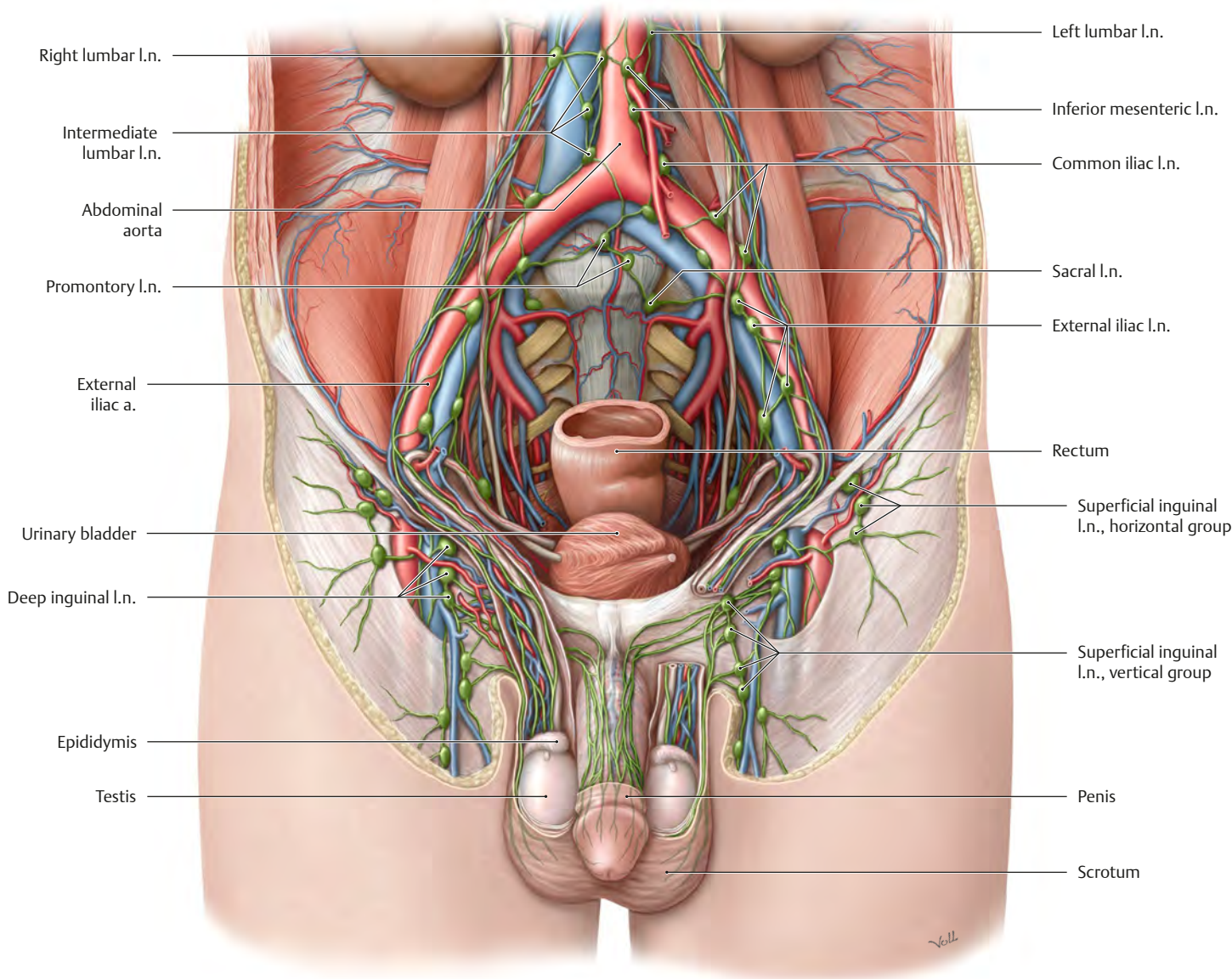
Body and glans of the clitoris – drain to deep inguinal and internal iliac nodes



B Lymphatic drainage of the clitoris.

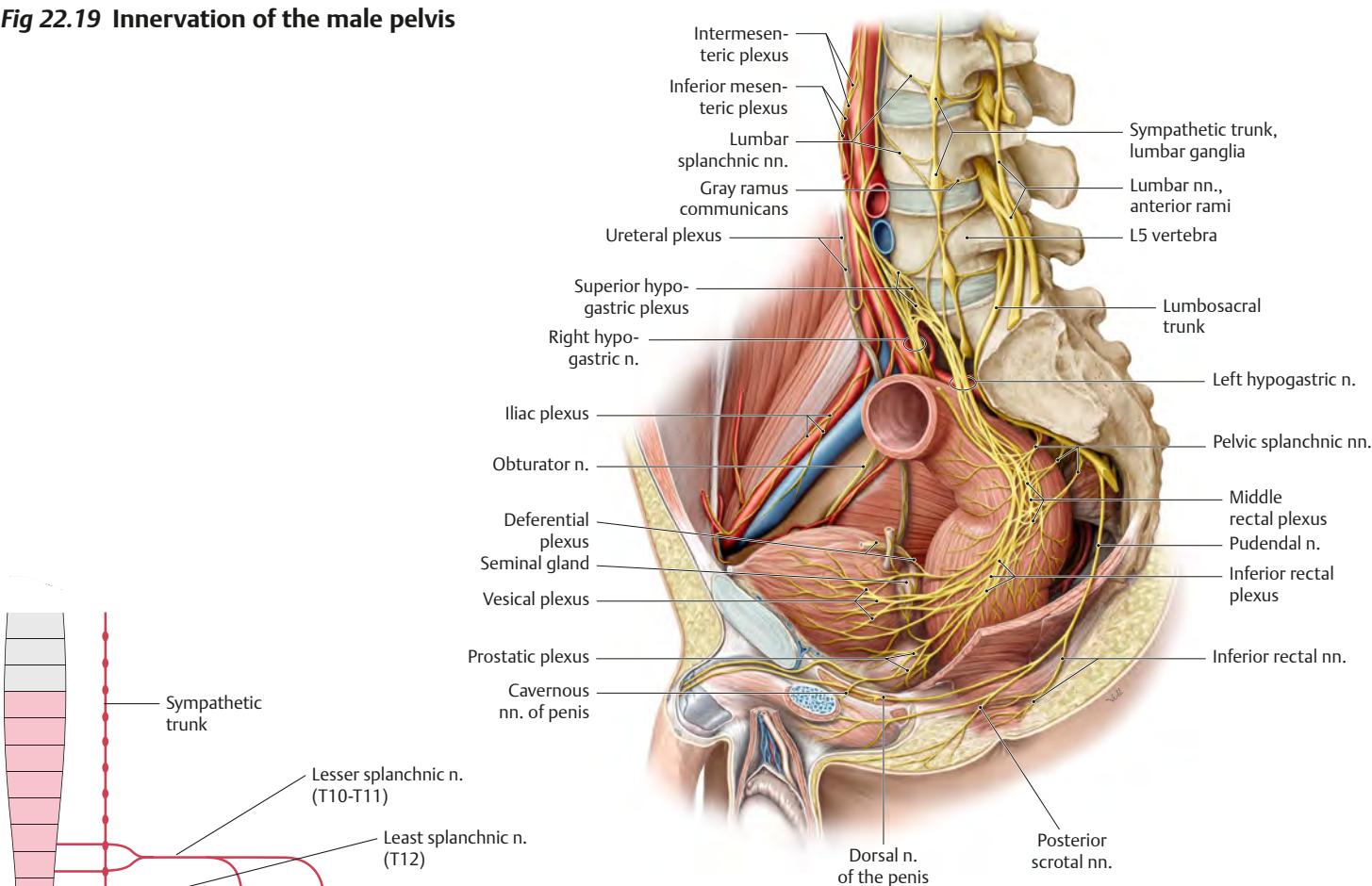
Lymph Nodes of the Genitalia

Fig. 22.16 Lymph nodes of the male genitalia
Anterior view. *Removed:* Gastrointestinal tract (except rectal stump) and peritoneum.

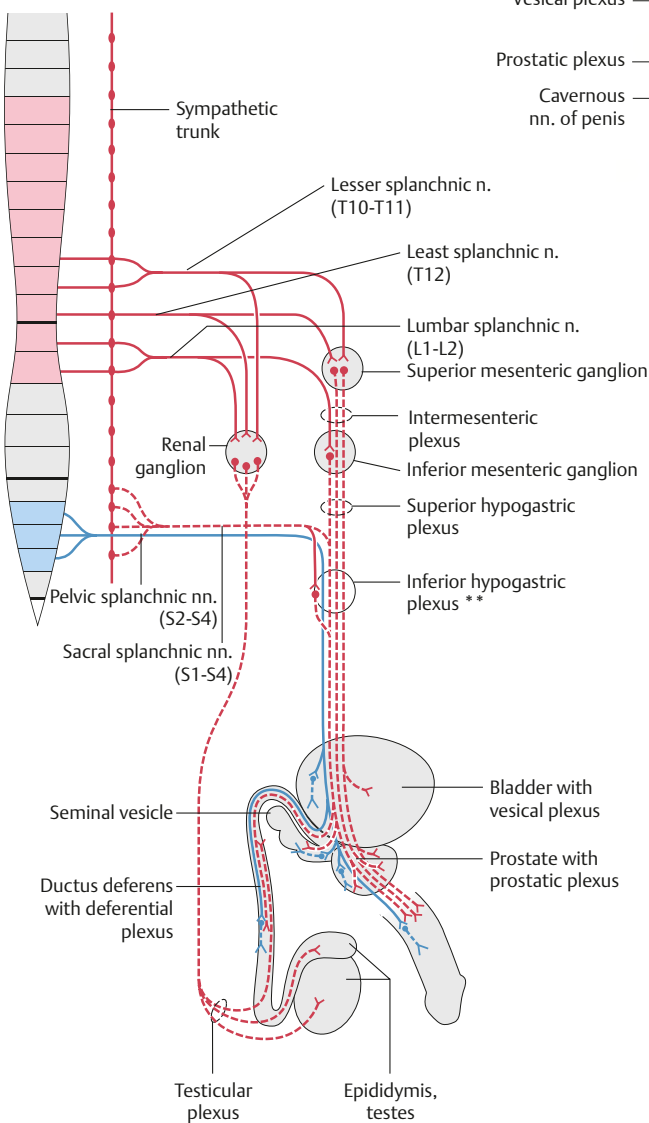


Autonomic Innervation of the Genital Organs

Fig 22.19 Innervation of the male pelvis



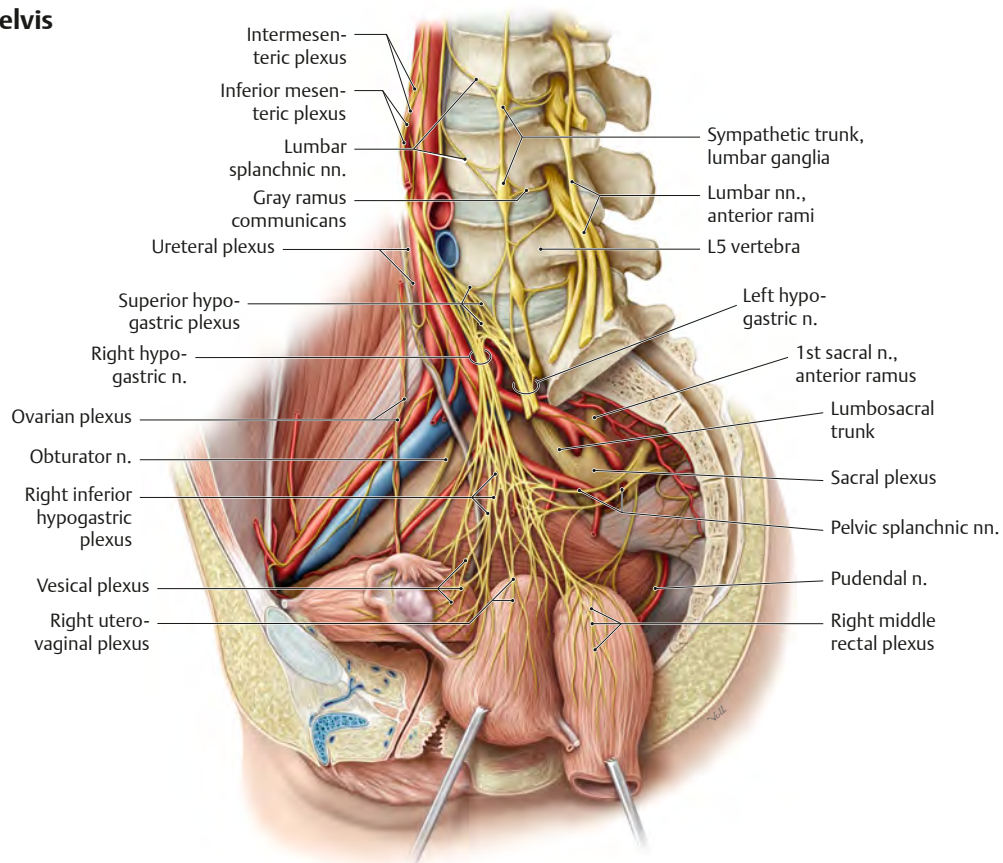
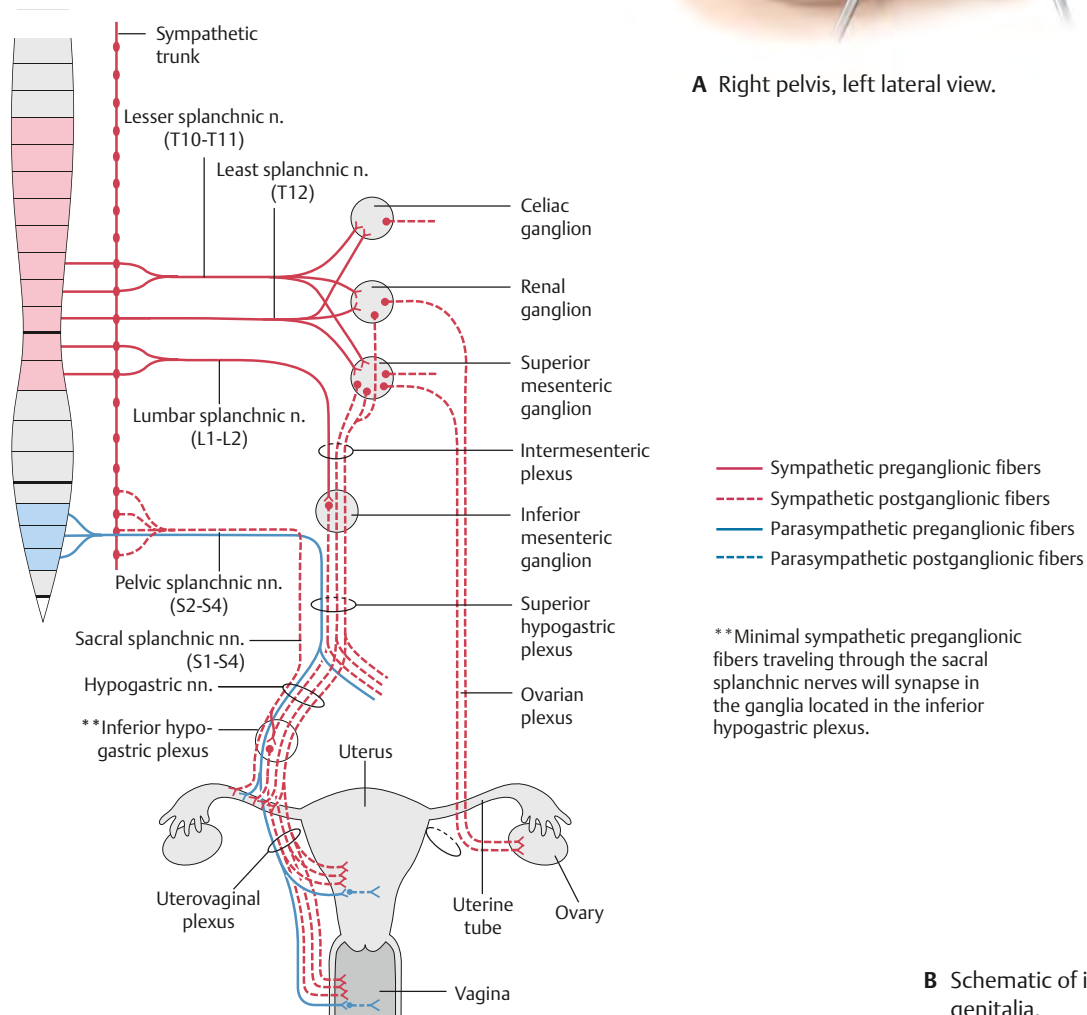
A Right pelvis, left lateral view.



- Sympathetic preganglionic fibers
- - - Sympathetic postganglionic fibers
- Parasympathetic preganglionic fibers
- - - Parasympathetic postganglionic fibers

**Minimal sympathetic preganglionic fibers traveling through the sacral splanchnic nerves will synapse in the ganglia located in the inferior hypogastric plexus

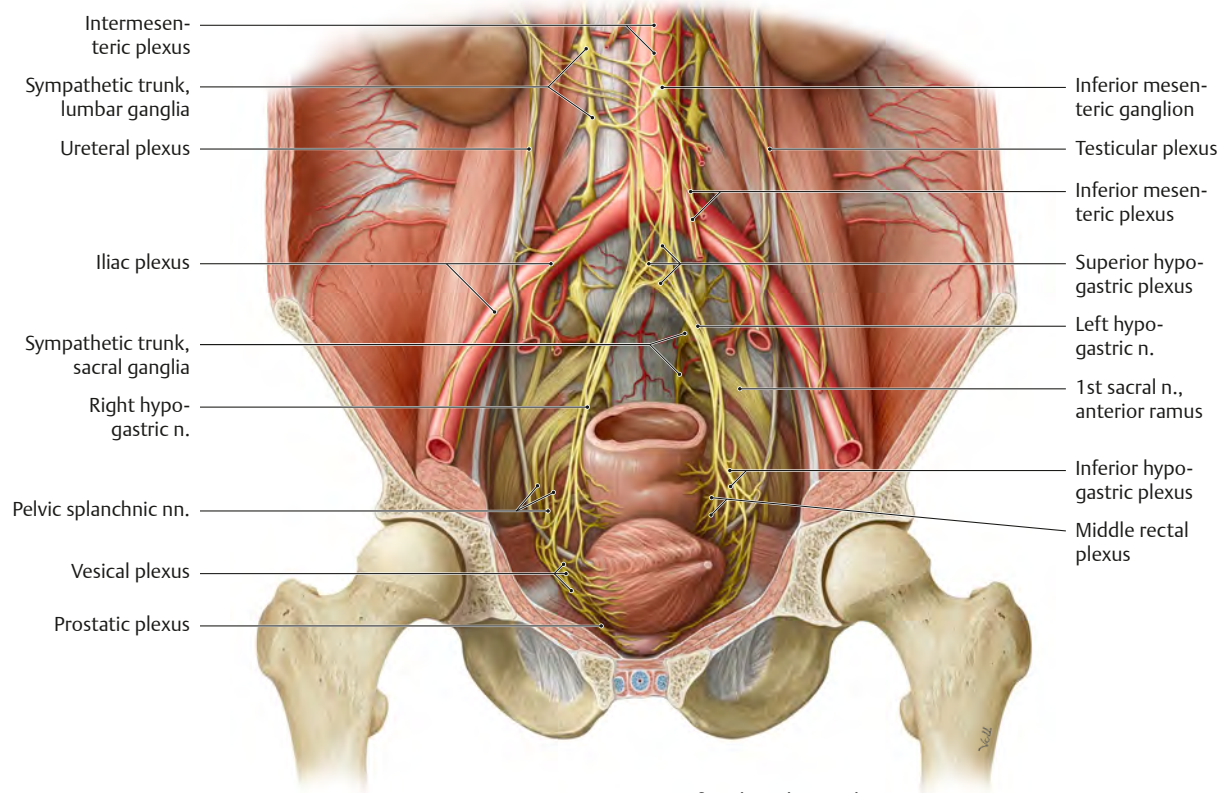
B Schematic of innervation of male genitalia.

Fig 22.20 Innervation of the female pelvis**A** Right pelvis, left lateral view.**B** Schematic of innervation of female genitalia.

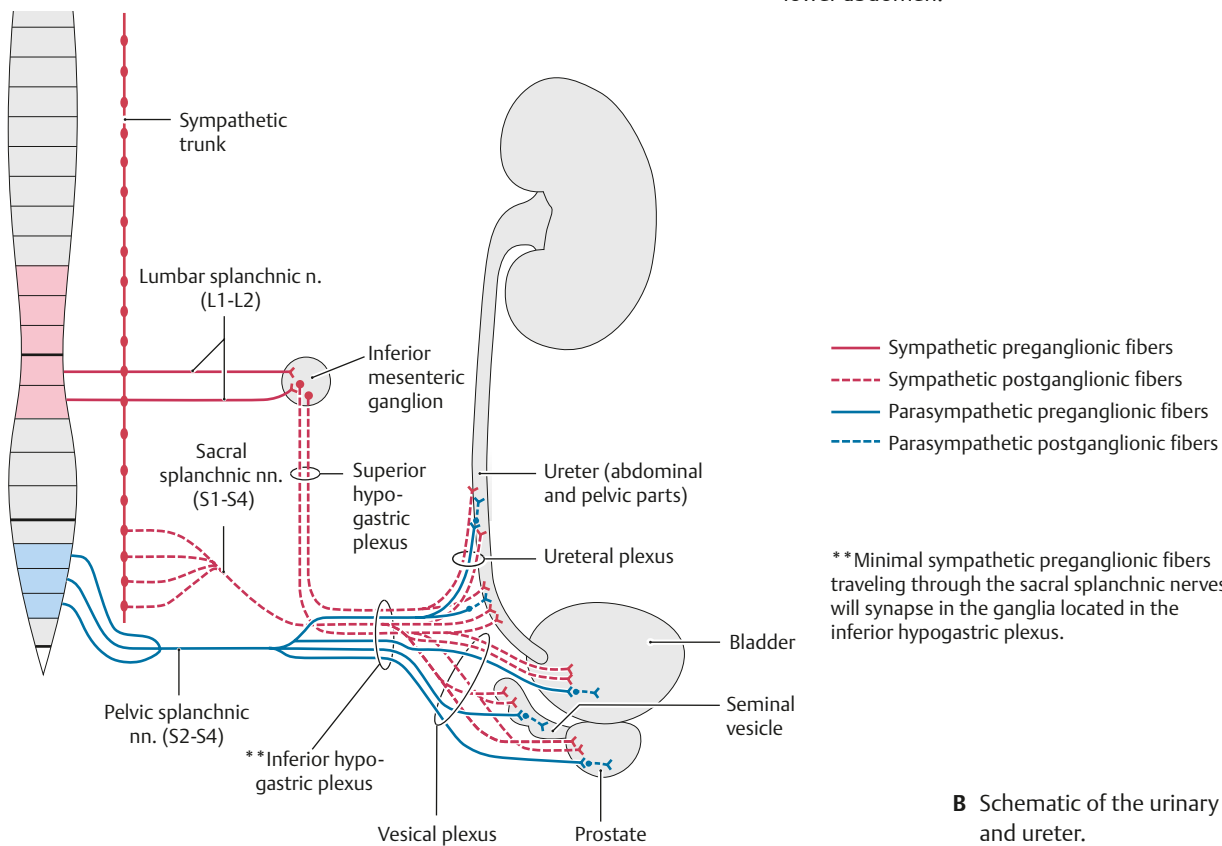
Autonomic Innervation of the Urinary Organs & Rectum

Fig 22.21 Innervation of the pelvic urinary organs

See pp. 215 and 217 for innervation of the kidneys and upper ureters.

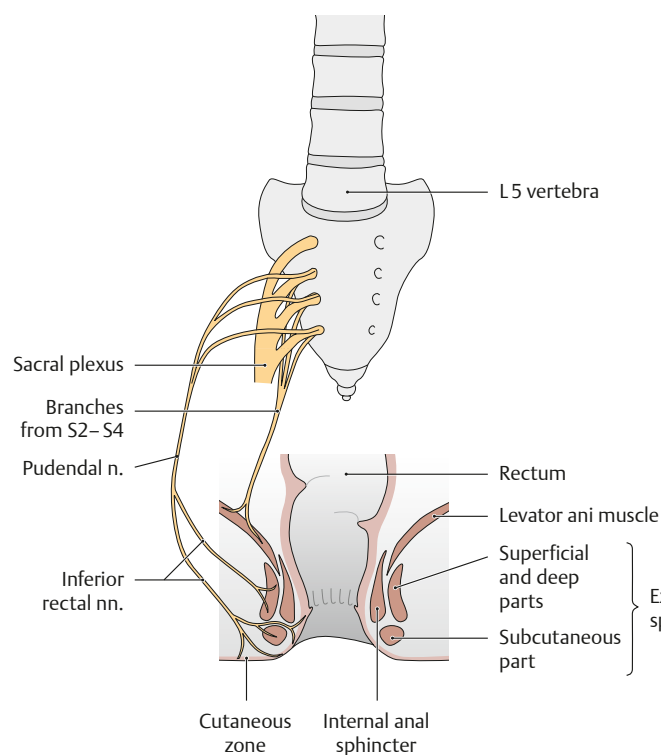


A Anterior view of male pelvis and lower abdomen.

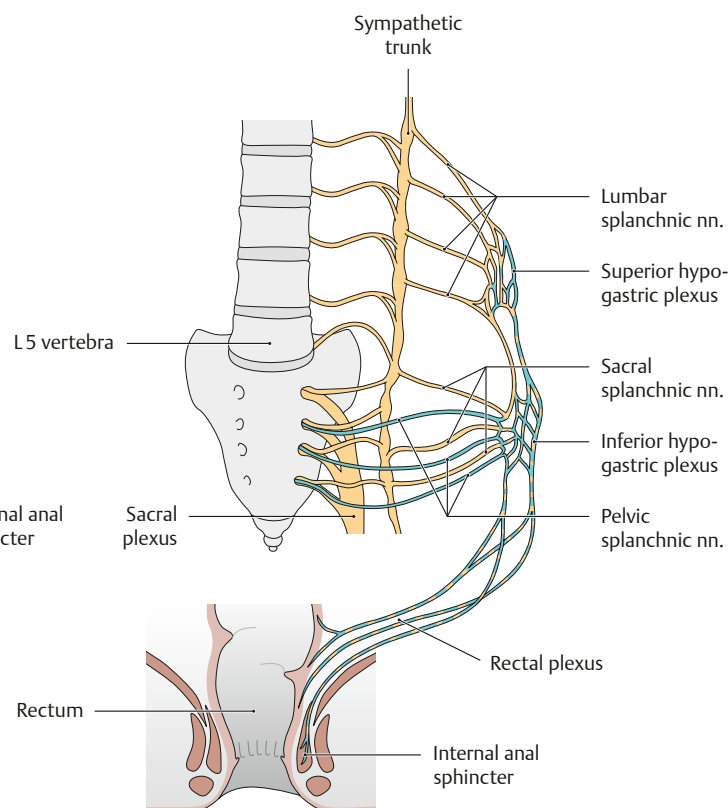


B Schematic of the urinary bladder and ureter.

Fig 22.22 Innervation of the anal sphincter mechanism



A Somatomotor and somatosensory innervation: The pudendal nerves and inferior rectal branches provide active, partly voluntary innervation of the external anal sphincter and levator ani muscles, and sensation for the anus and perianal skin.



B Visceromotor and viscerosensory innervation: Pelvic splanchnic nerves (S2-4) innervate the internal anal sphincter, which helps to maintain closure of the anal canal. They also supply sensation to the wall of the rectum, particularly the stretch receptors in the rectal ampulla, which when stretched trigger an awareness of the need to defecate.



Clinical box 22.2

Mechanism of defecation (after Wedel)

Both defecation and continence are under central nervous system control involving such diverse structures as the cerebral cortex, muscles of the abdomen and pelvis and perianal skin.

Filling of the rectal ampulla and stimulation of local stretch receptors in the ampullary wall. When the fecal bolus is propelled into the ampulla, mechanoreceptors detect distension and transmit the information to the sensory cortex, which perceives the urge to defecate.

Rectoanal inhibitory reflex and relaxation of the voluntarily innervated sphincters. When the ampulla fills, the intrarectal pressure increases and the internal anal sphincter relaxes. This is followed by voluntary relaxation of the puborectalis sling and the external anal sphincter, which results in the straightening of the anorectal angle and widening of the anal canal.

Propulsion of the fecal column. Rectal evacuation is assisted by a direct involuntary increase in pressure in the rectal area and by simultaneous increase in pressure by the contraction of voluntarily innervated muscles in the abdomen wall, pelvic floor, and diaphragm. With propulsion of the fecal column, the hemorrhoidal cushions are drained and pushed out.

Completion of defecation. After the sphincter apparatus allows the fecal column to pass through, it comes in contact with the highly sensitive anoderm, which perceives the volume, consistency and location of the stool. This perception initiates the voluntary process of completing defecation, which is marked by the contraction of the sphincter apparatus and filling of the hemorrhoidal plexus.

Neurovasculature of the Male & Female Perineum

Fig. 22.23 Nerves of the male perineum and genitalia
Lithotomy position.

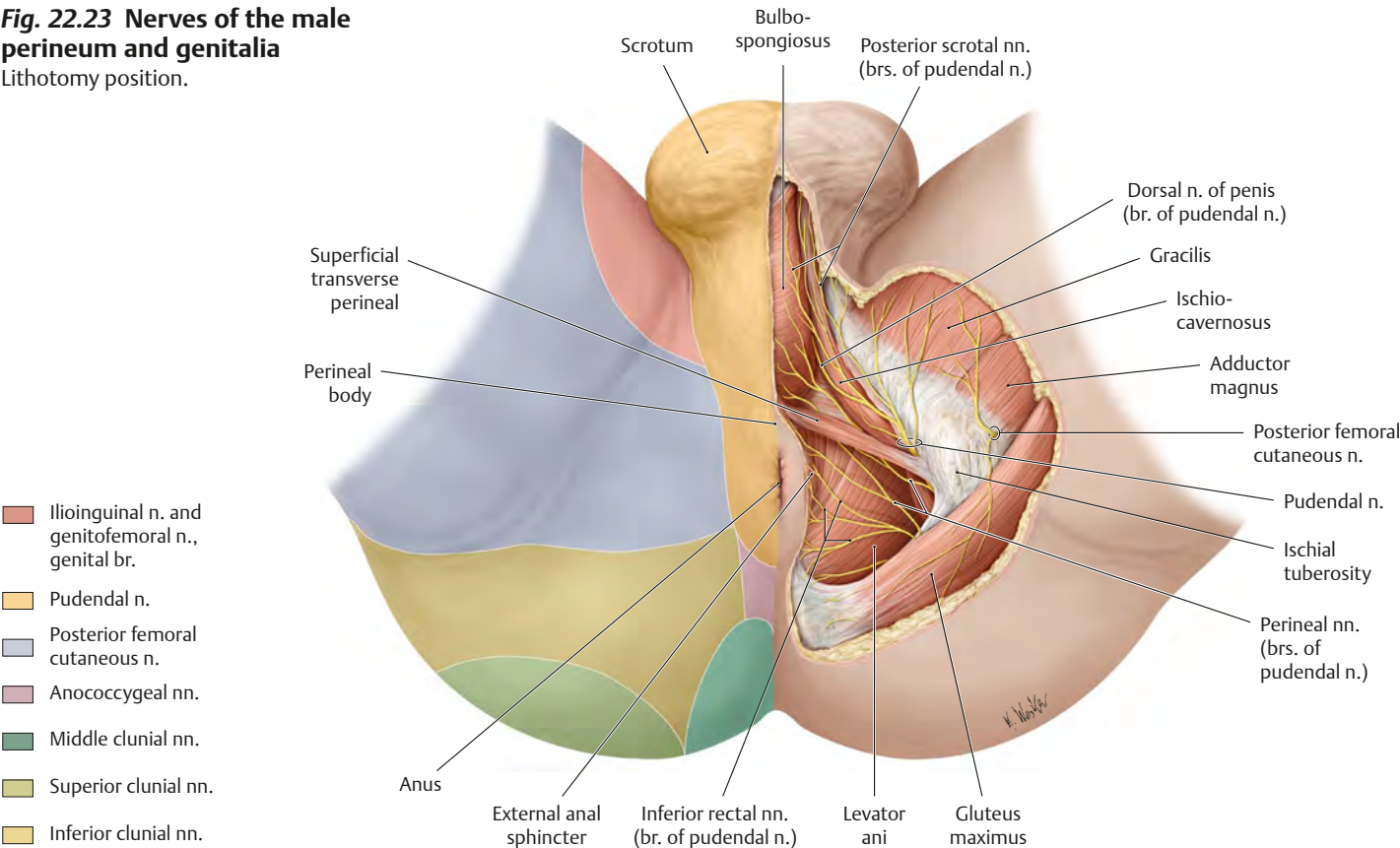


Fig. 22.24 Neurovasculature of the male perineum

Lithotomy position.
Removed from left side:
Perineal membrane,
bulbospongiosus, and
root of penis.

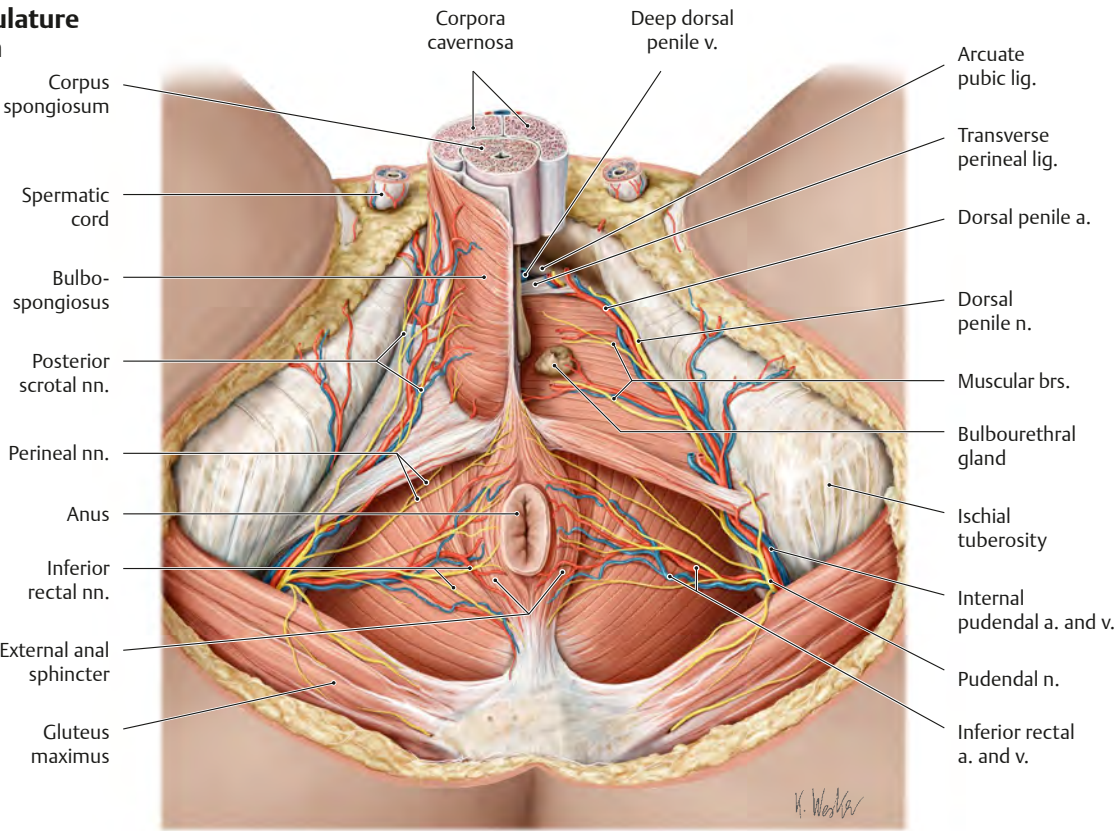


Fig. 22.25 Nerves of the female perineum and genitalia

Sensory innervation of the female perineum. Lithotomy position.

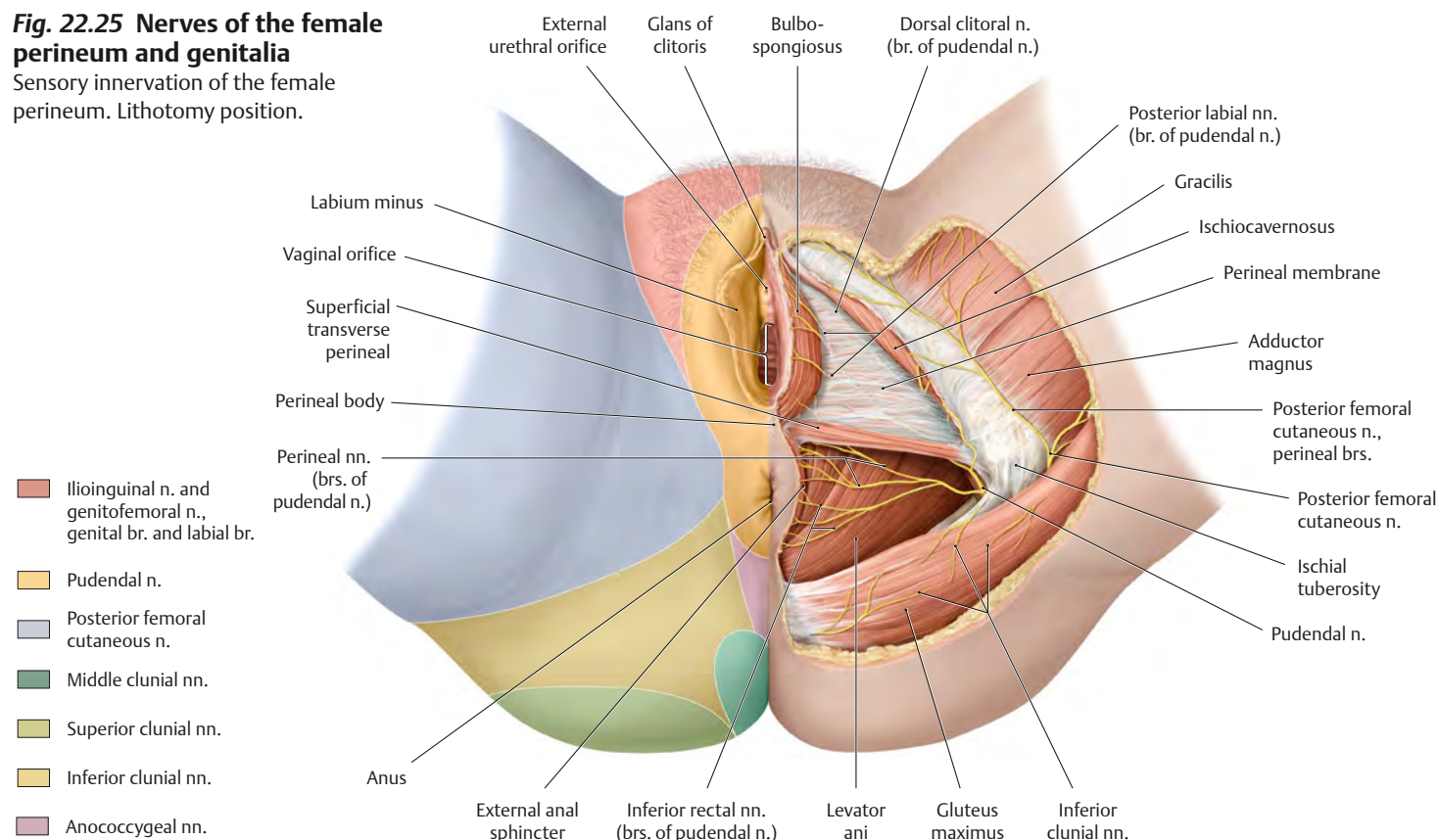
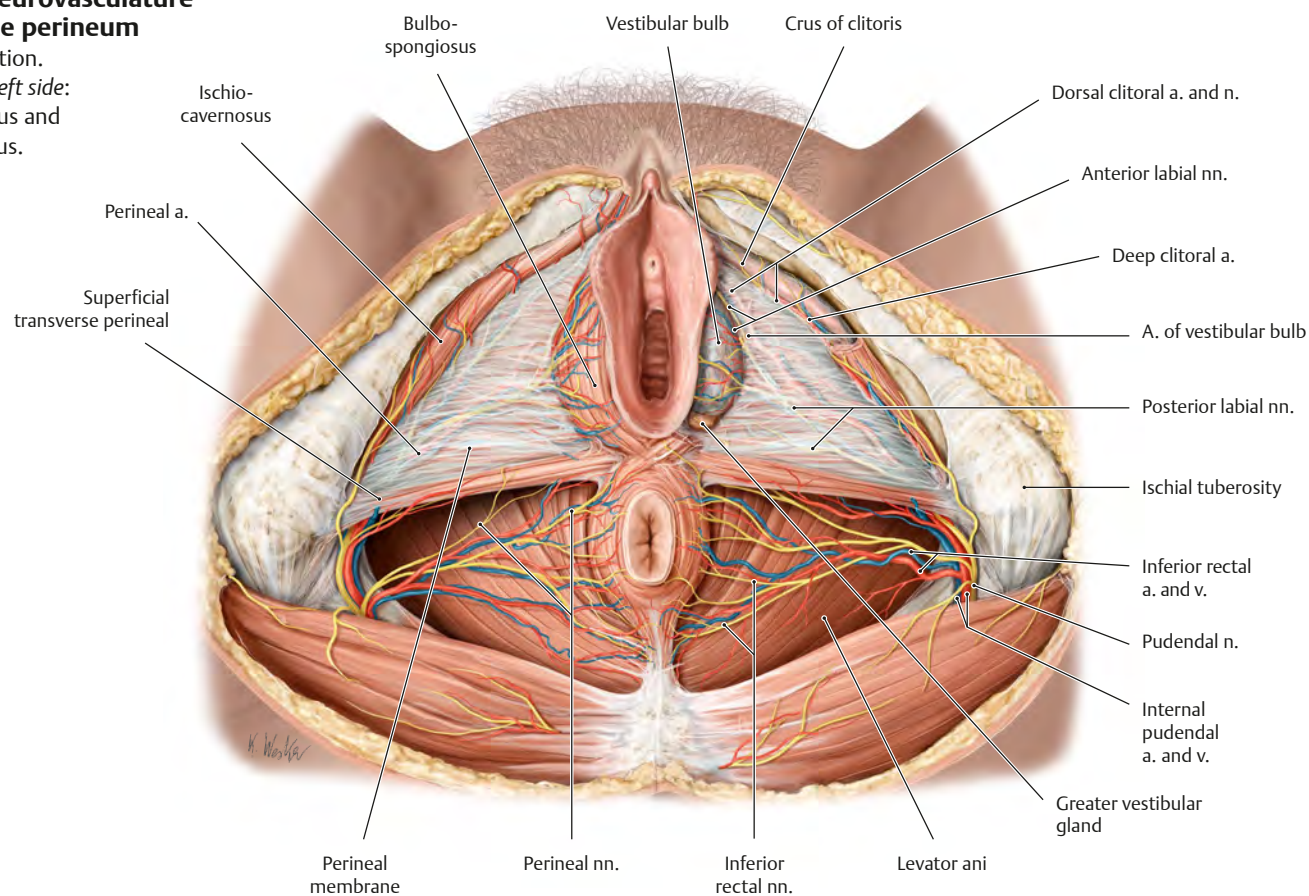


Fig. 22.26 Neurovasculature of the female perineum

Lithotomy position.

Removed from left side:
Bulbospongiosus and ischiocavernosus.



23 Sectional & Radiographic Anatomy

Sectional Anatomy of the Pelvis & Perineum

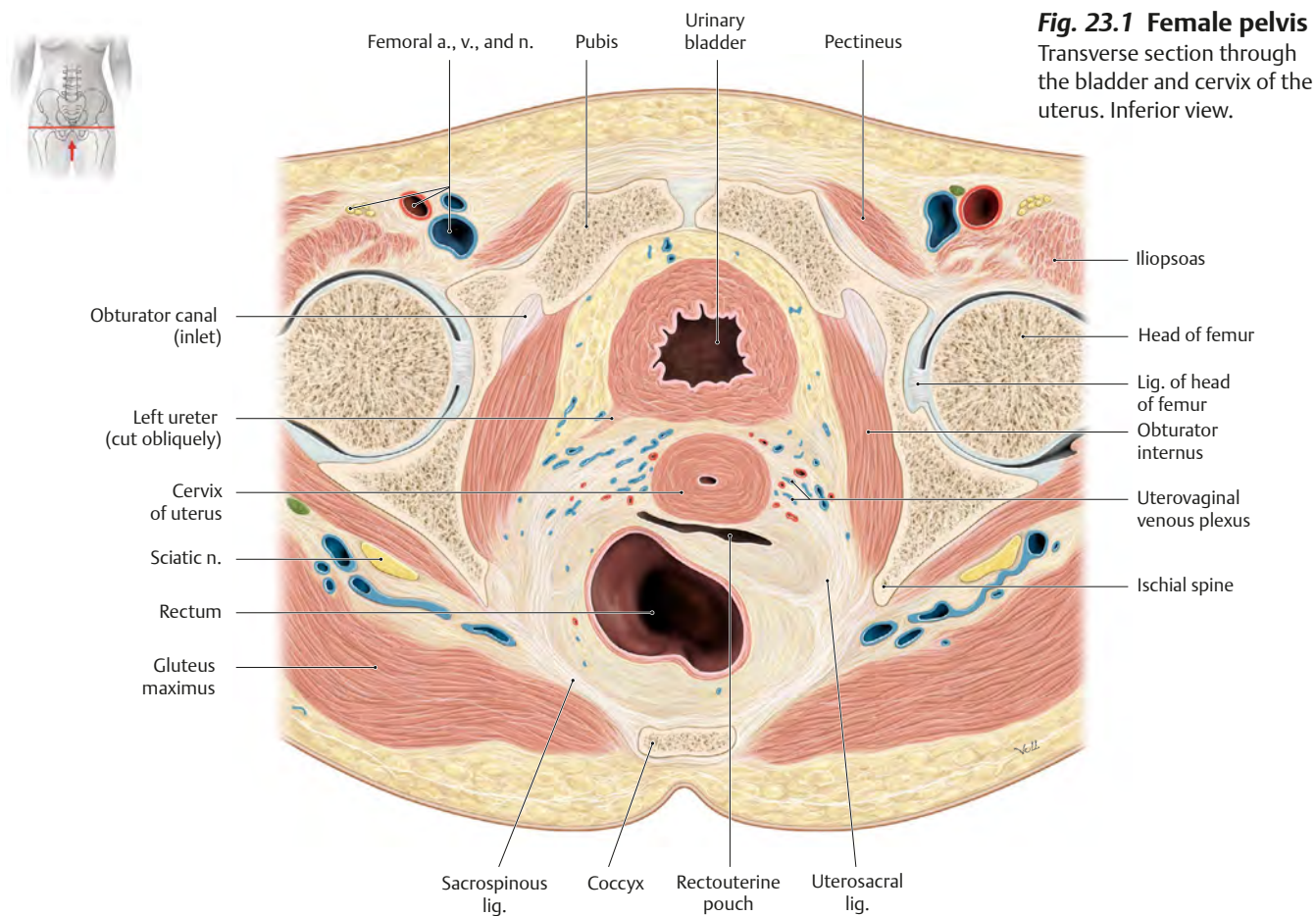


Fig. 23.1 Female pelvis
Transverse section through the bladder and cervix of the uterus. Inferior view.

Fig. 23.2 Male pelvis
Transverse section through the bladder and seminal glands. Inferior view.

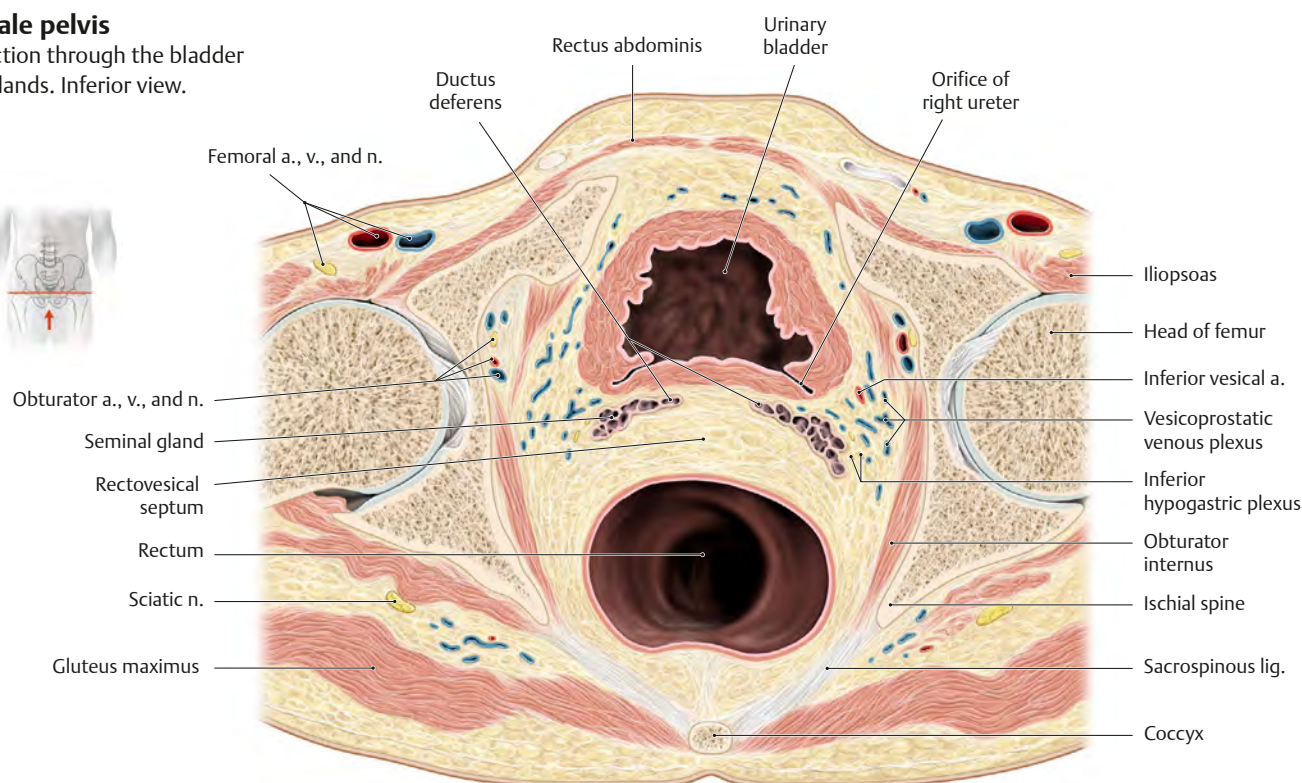
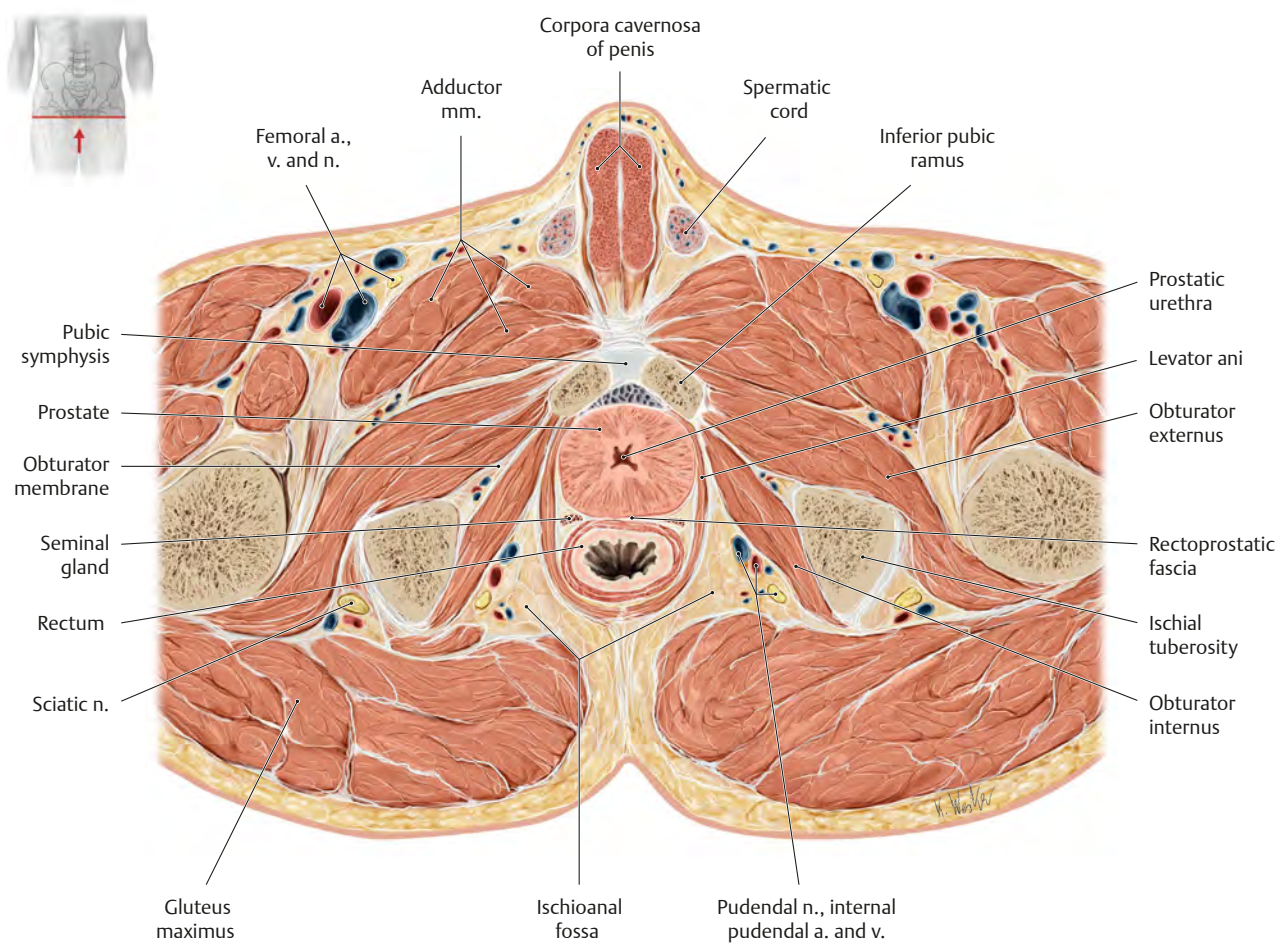


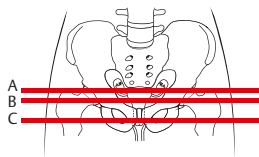
Fig. 23.3 Male pelvis

Transverse section through the prostate gland and anal canal. Inferior view.

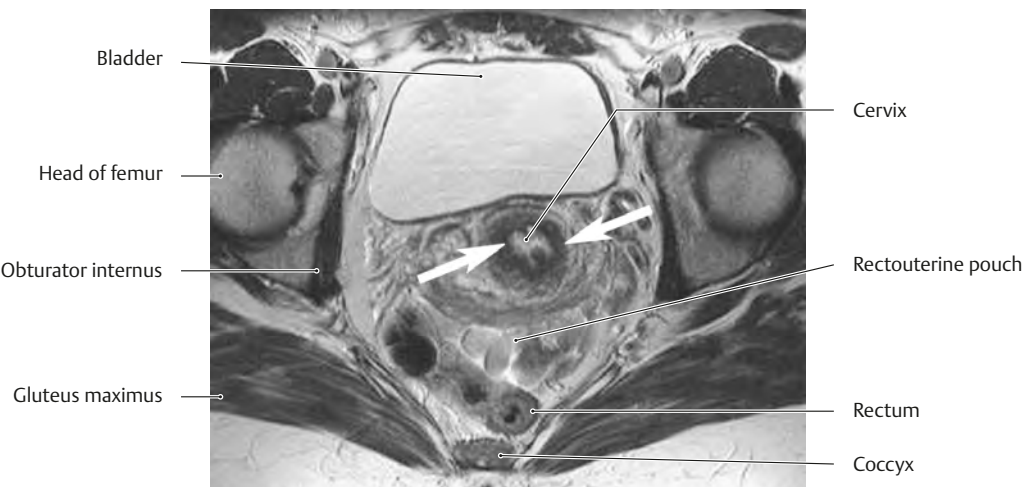
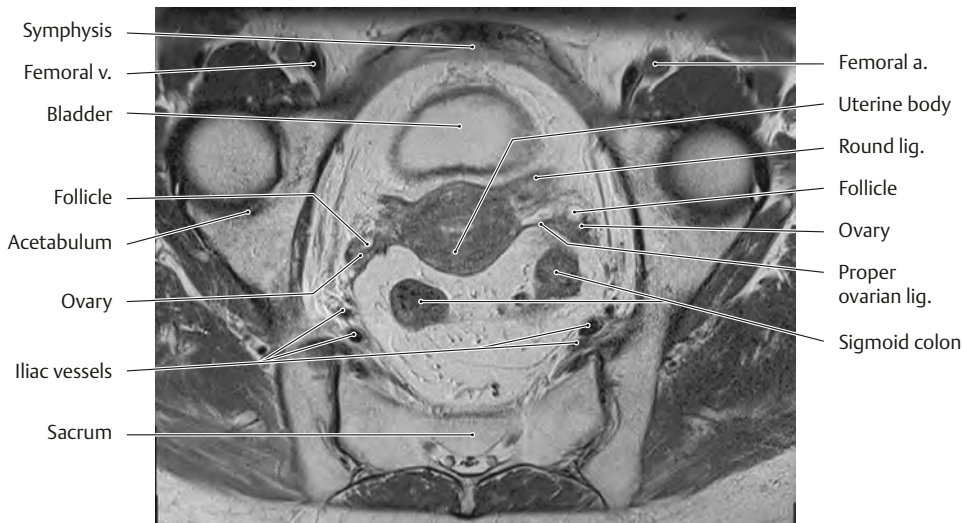


Radiographic Anatomy of the Female Pelvis

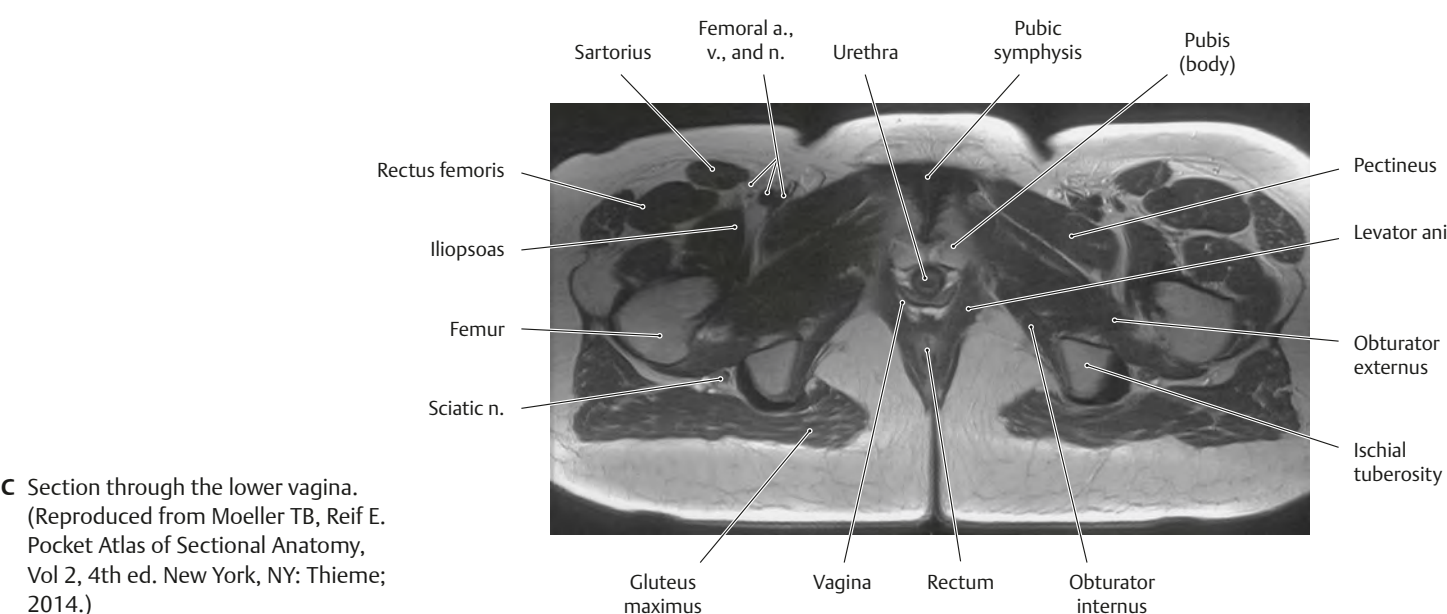
Fig 23.4 MRI of the female pelvis
Transverse section, inferior view.



A Section through the body of the uterus.
(Reproduced from Krombach GA, Mahnken AH. *Body Imaging: Thorax and Abdomen*. New York, NY: Thieme; 2018.)

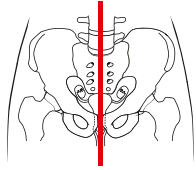


B Section through the cervical canal.
The image shows the low-signal intensity cervical stroma (arrows), which surrounds the narrow high-signal intensity cervical canal. (Reproduced from Hamm B. et al. *MRT von Abdomen und Becken*, 2nd ed. Stuttgart: Thieme; 2006.)

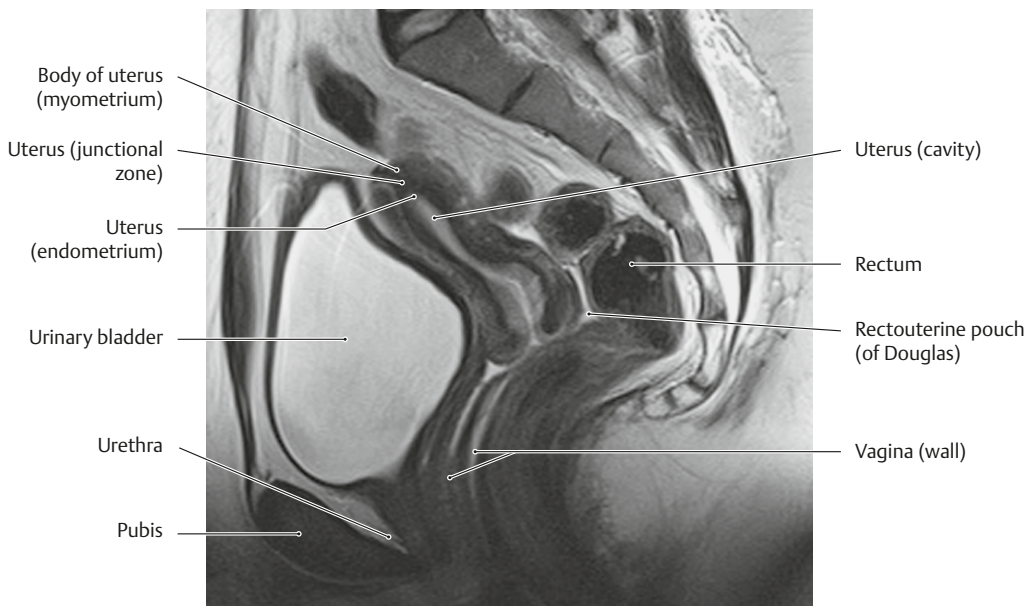
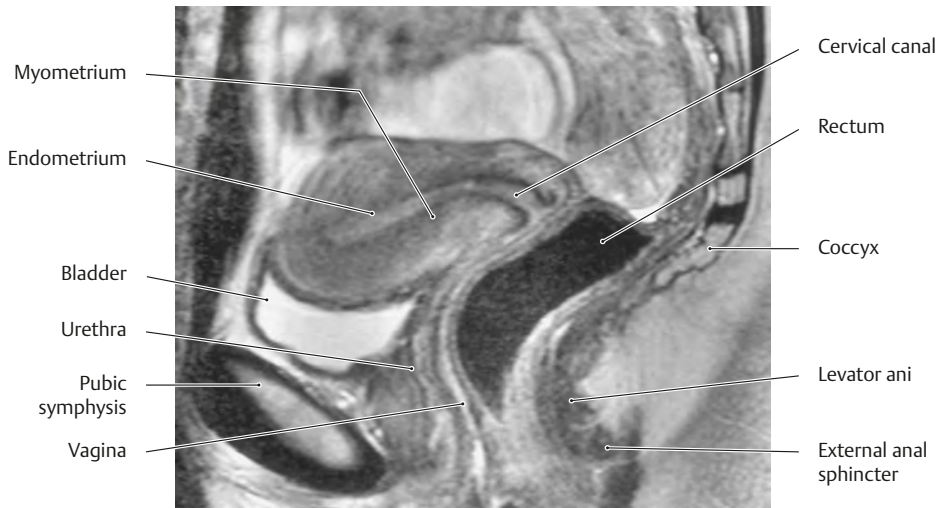


C Section through the lower vagina.
(Reproduced from Moeller TB, Reif E. *Pocket Atlas of Sectional Anatomy*, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

Fig. 23.5 MRI of the female pelvis
Sagittal section, left lateral view

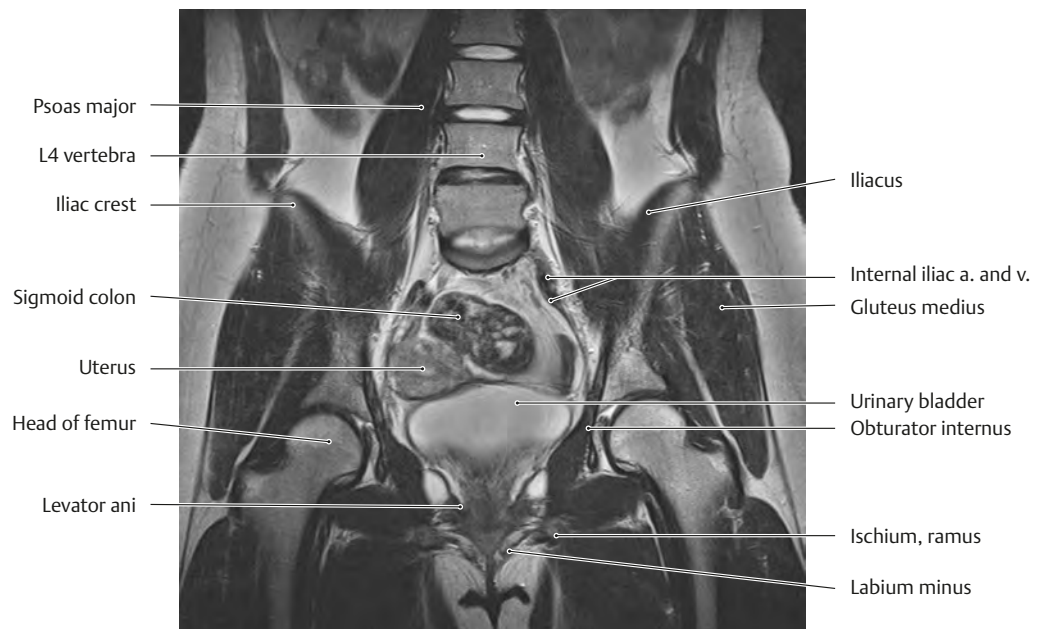
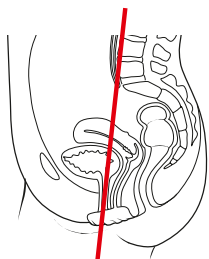


A Position of the uterus with a near empty bladder. The image shows the uterus in the first half of the menstrual cycle (proliferative phase) with narrow endometrium and relatively low-signal intensity of the myometrium. (Reproduced from Hamm B. et al. MRT von Abdomen und Becken, 2nd ed. Stuttgart: Thieme; 2006.)



B Position of the uterus with a full bladder. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

Fig. 23.6 MRI of the female pelvis
Coronal section, anterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)



Radiographic Anatomy of the Male Pelvis

Fig. 23.7 MRI of the male pelvis
Sagittal section, left lateral view.
(Reproduced from Hamm B. et al. MRT von Abdomen und Becken, 2nd ed. Stuttgart: Thieme; 2006.)

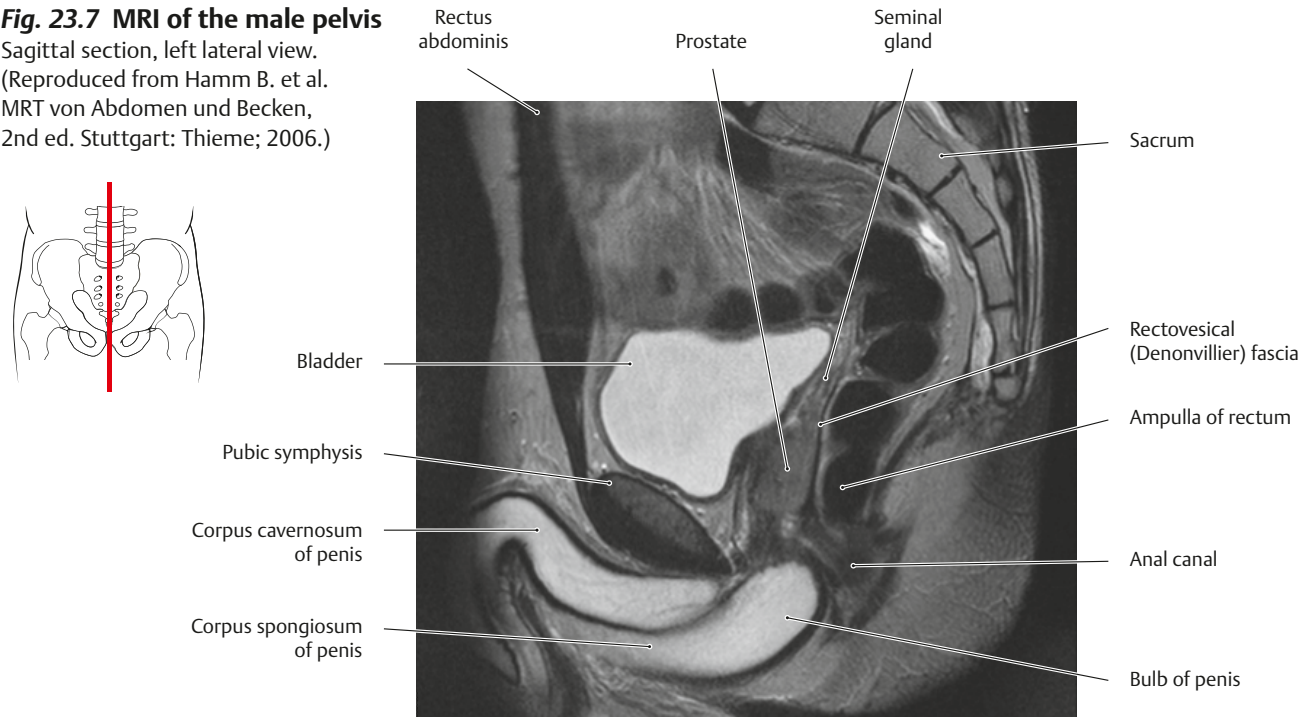
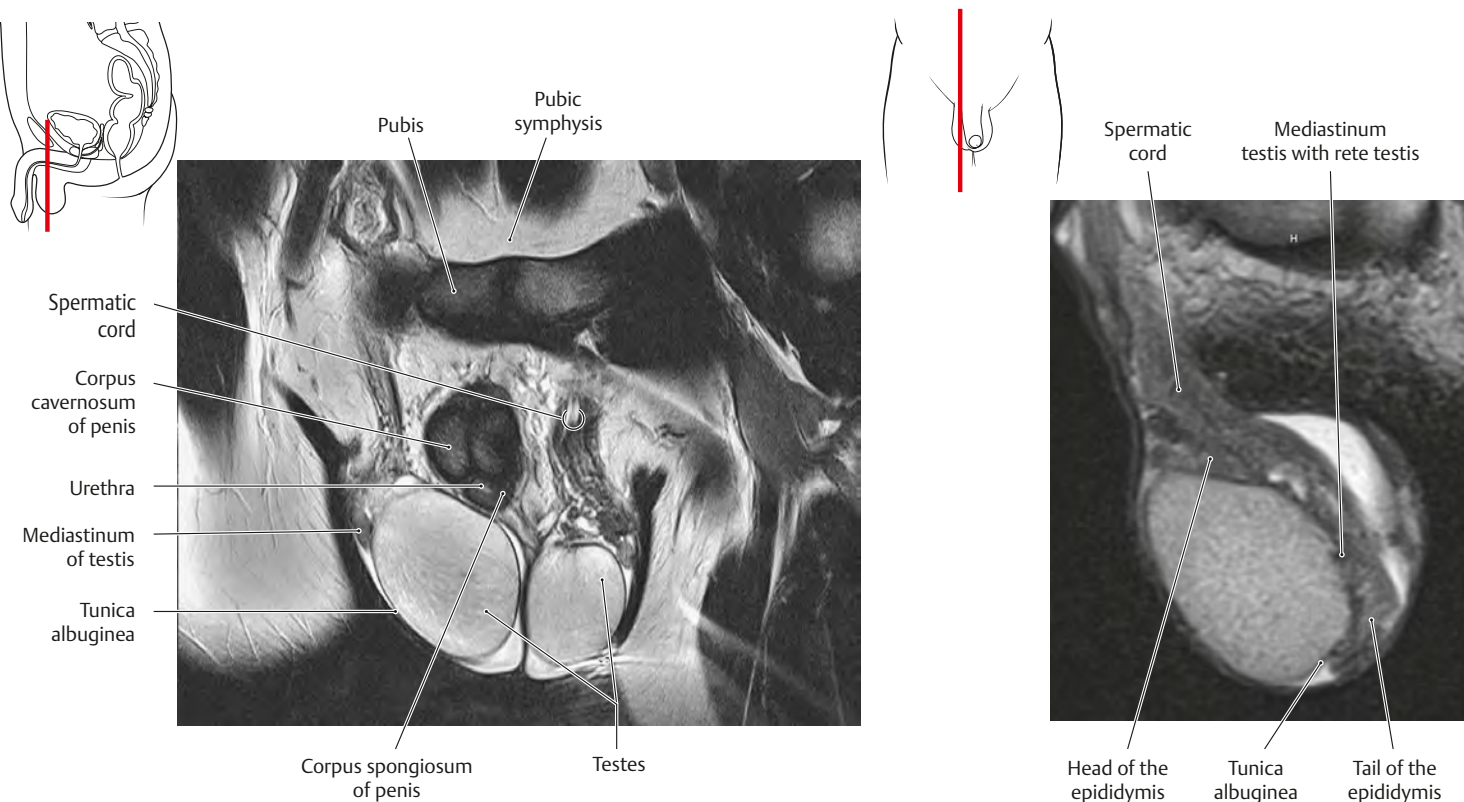


Fig. 23.8 MRI of the testes

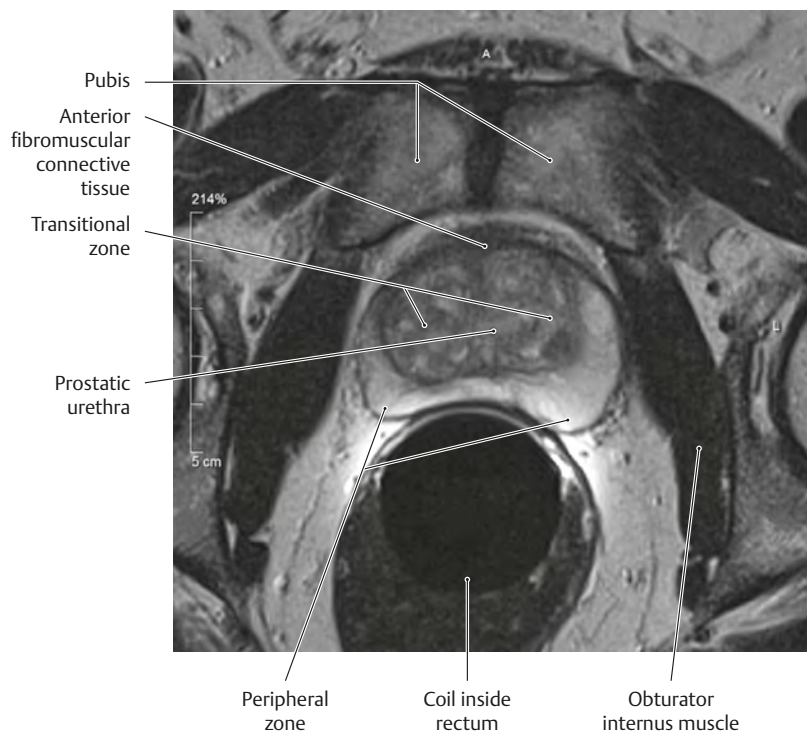
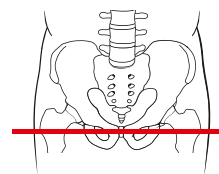


A Coronal section, anterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

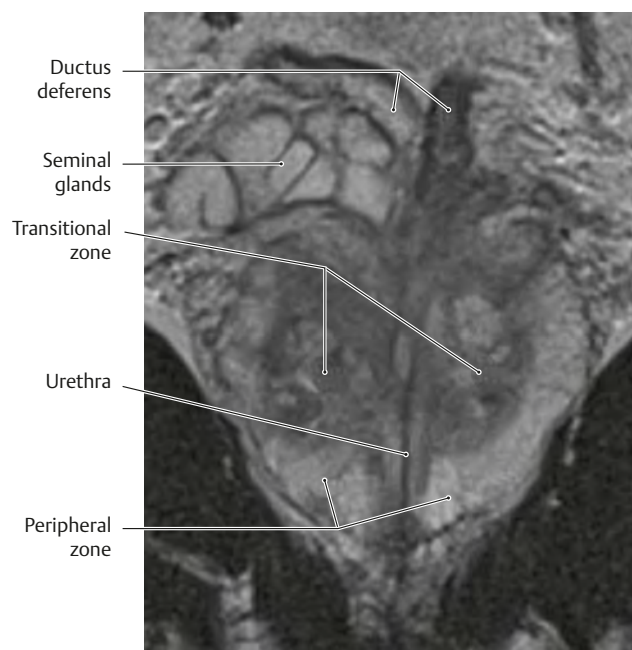
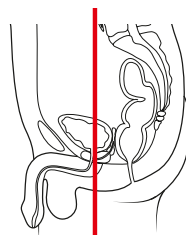
B Parasagittal section, T2 W image. (Reproduced from Krombach GA, Mahnken AH. Body Imaging: Thorax and Abdomen. New York, NY: Thieme; 2018.)

Fig. 23.9 MRI of the prostate

(Reproduced from Krombach GA, Mahnken AH. Body Imaging: Thorax and Abdomen. New York, NY: Thieme; 2018.)



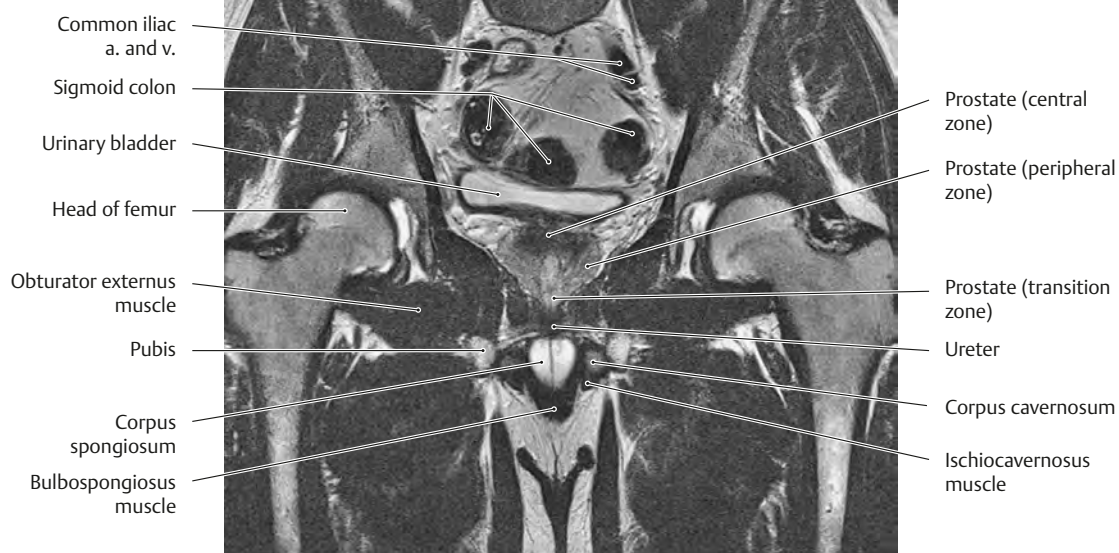
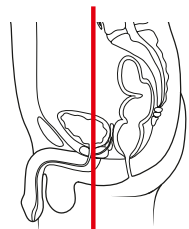
A Transverse section, T2W image.

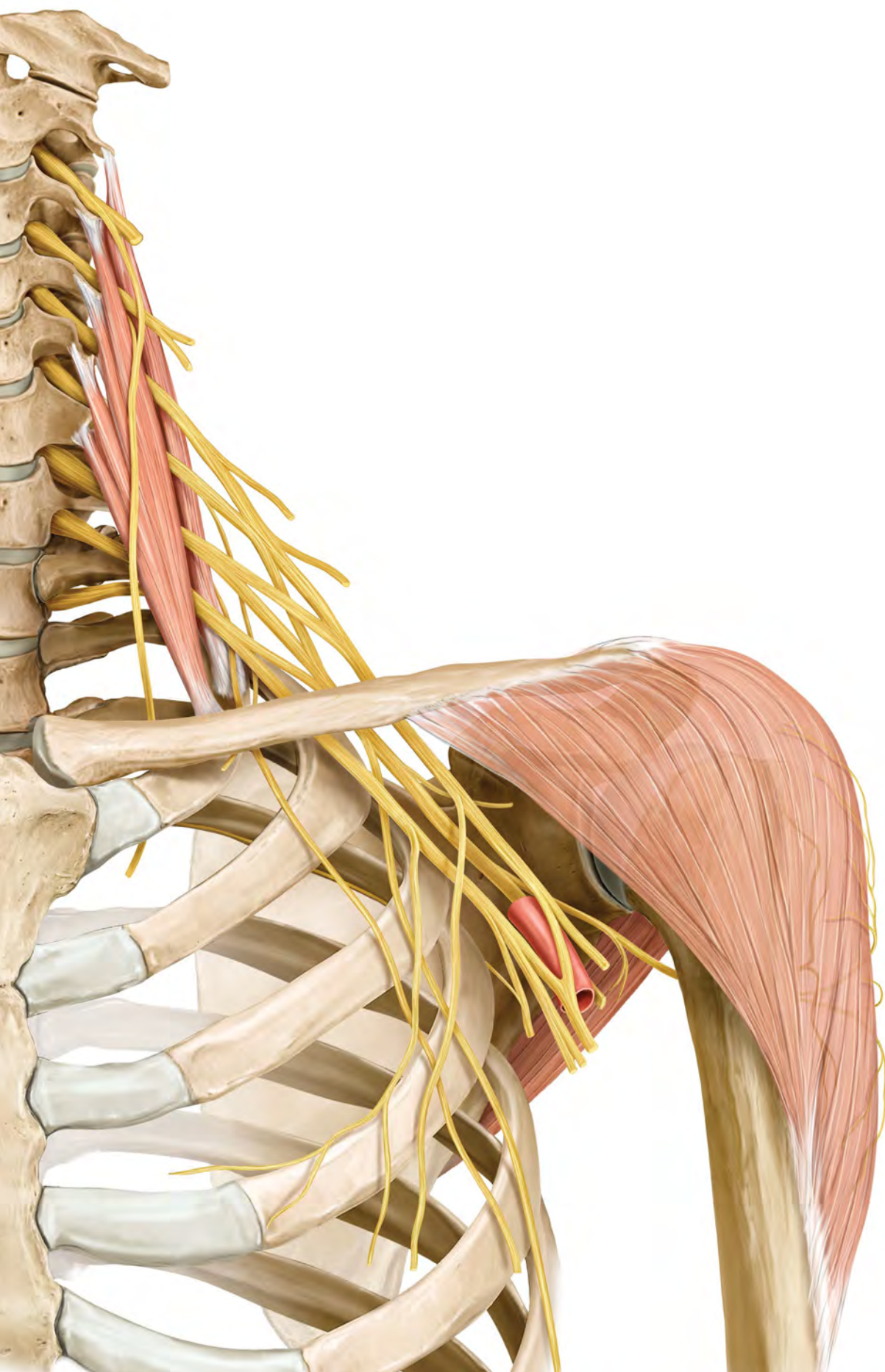


B Coronal section, T2W image.

Fig. 23.10 MRI of the male pelvis

Coronal section. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)





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24 Surface Anatomy

Surface Anatomy

Fig. 24.1 Regions of the upper limb

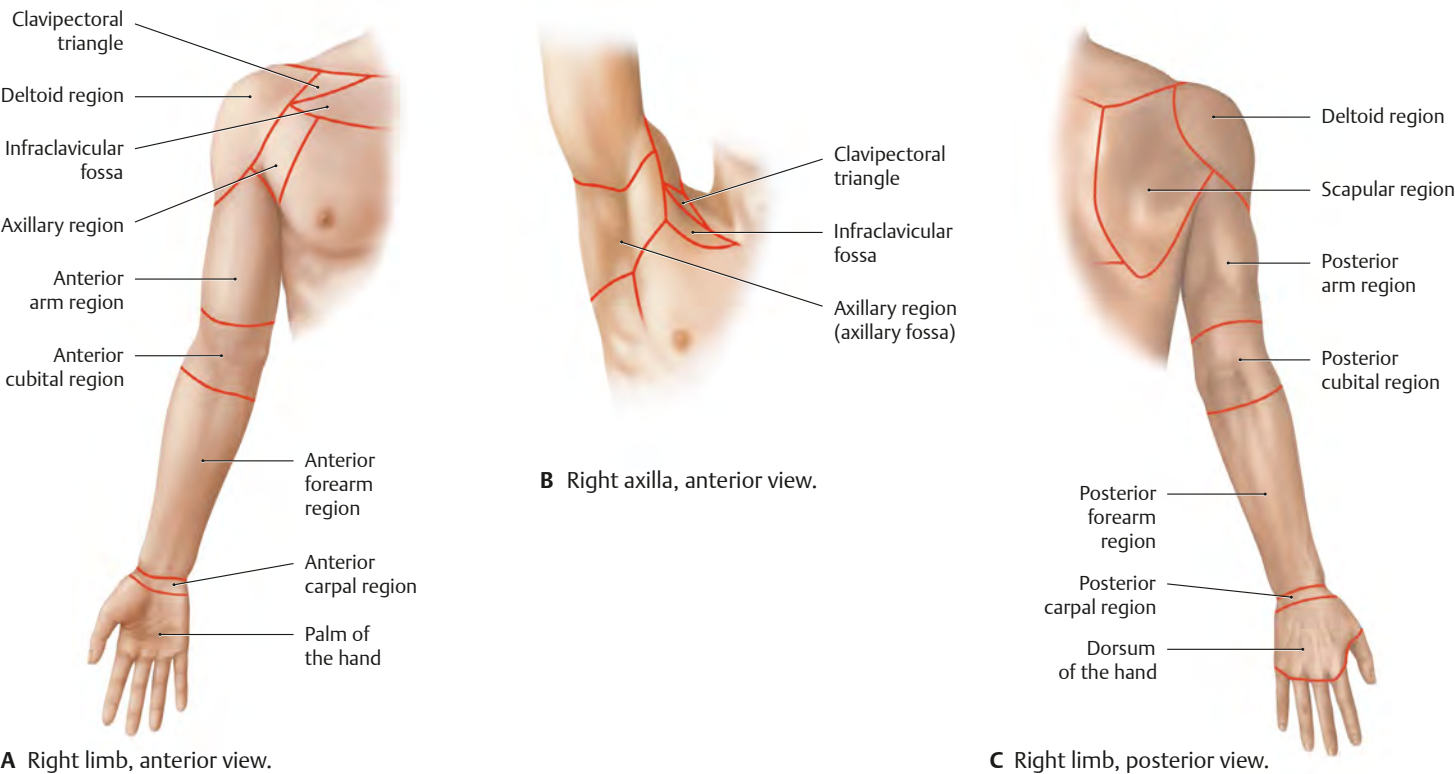


Fig. 24.2 Palpable musculature of the upper limb

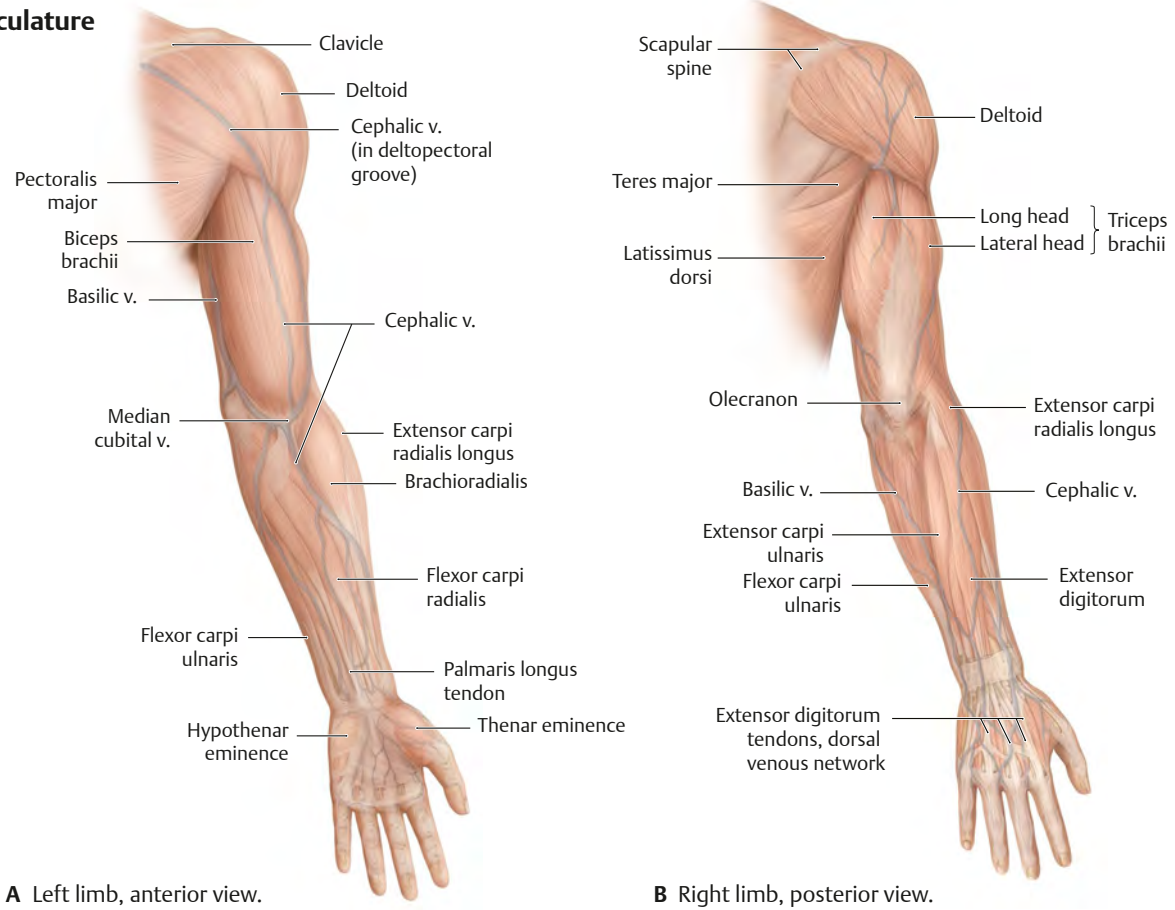


Fig. 24.3 Palpable bony prominences of the upper limb

Except for the lunate and trapezoid bones, all of the bones in the upper limb are palpable to some degree through the skin and soft tissues.

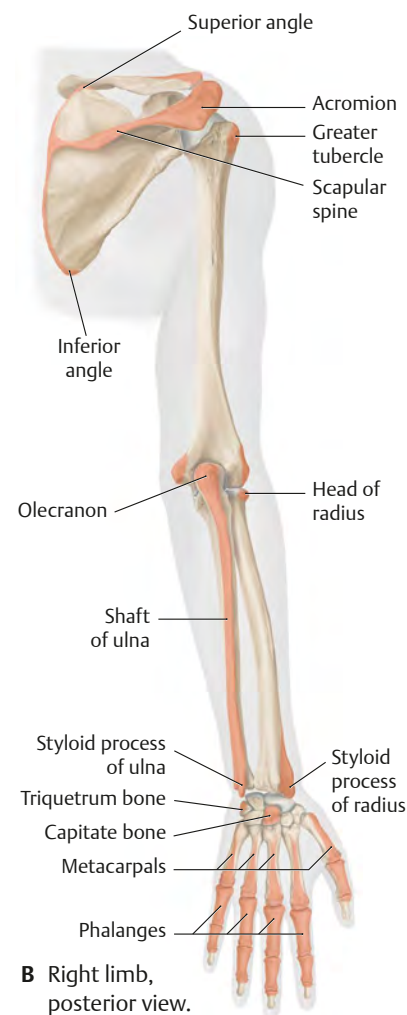
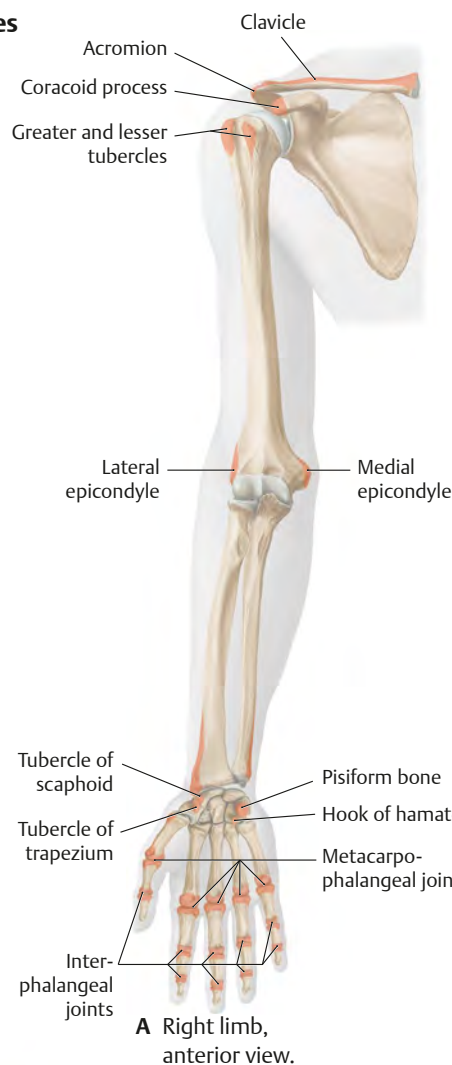
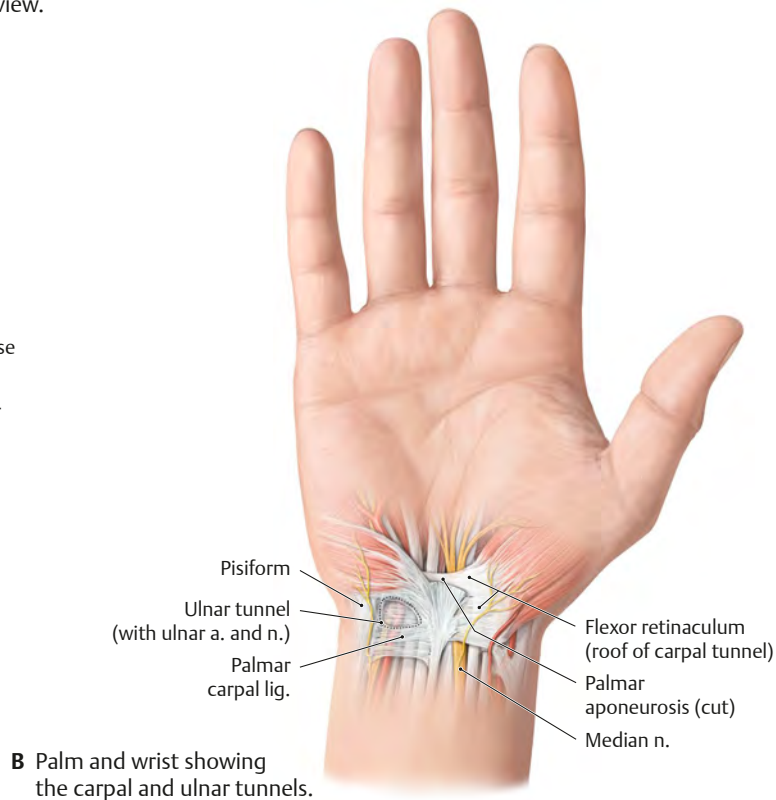
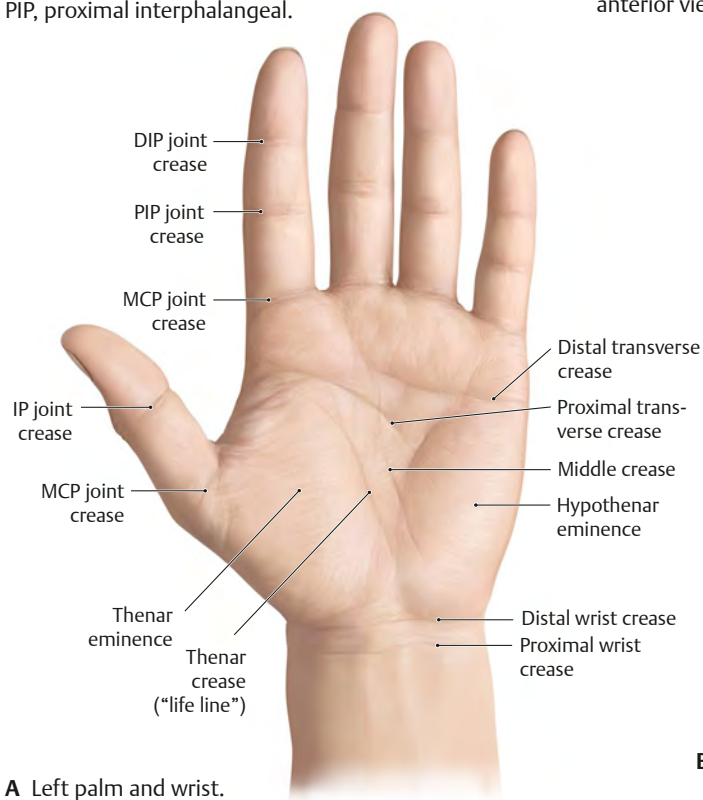


Fig. 24.4 Surface anatomy of the wrist and hand

DIP, distal interphalangeal;
IP, interphalangeal;
MCP, metacarpophalangeal;
PIP, proximal interphalangeal.



25 Shoulder & Arm

Bones of the Upper Limb

Fig. 25.1 Bones of the upper limb
 Right limb. The upper limb is subdivided into three regions: arm, forearm, and hand. The shoulder girdle (clavicle and scapula) joins the upper limb to the thorax at the sternoclavicular joint.

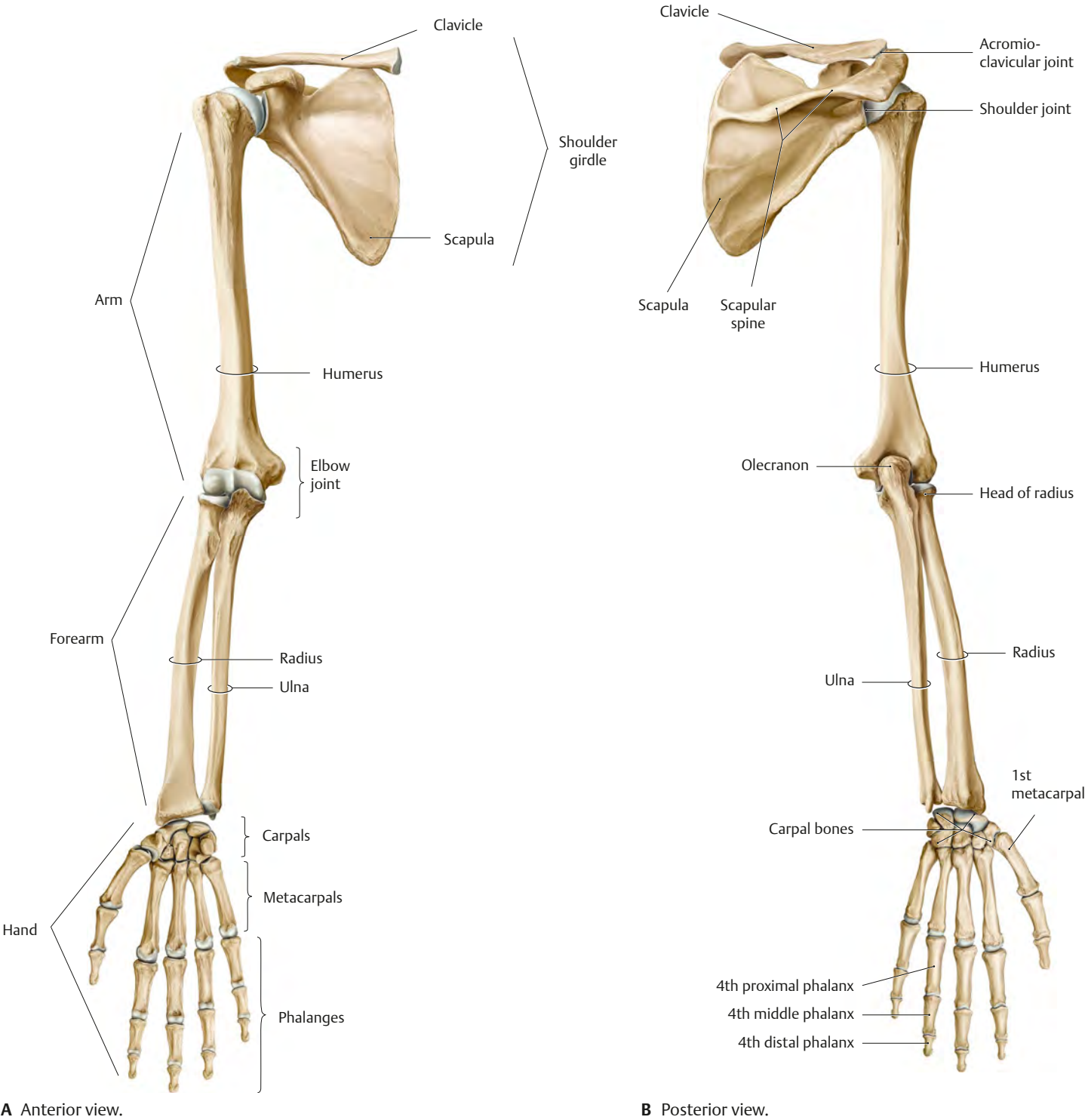
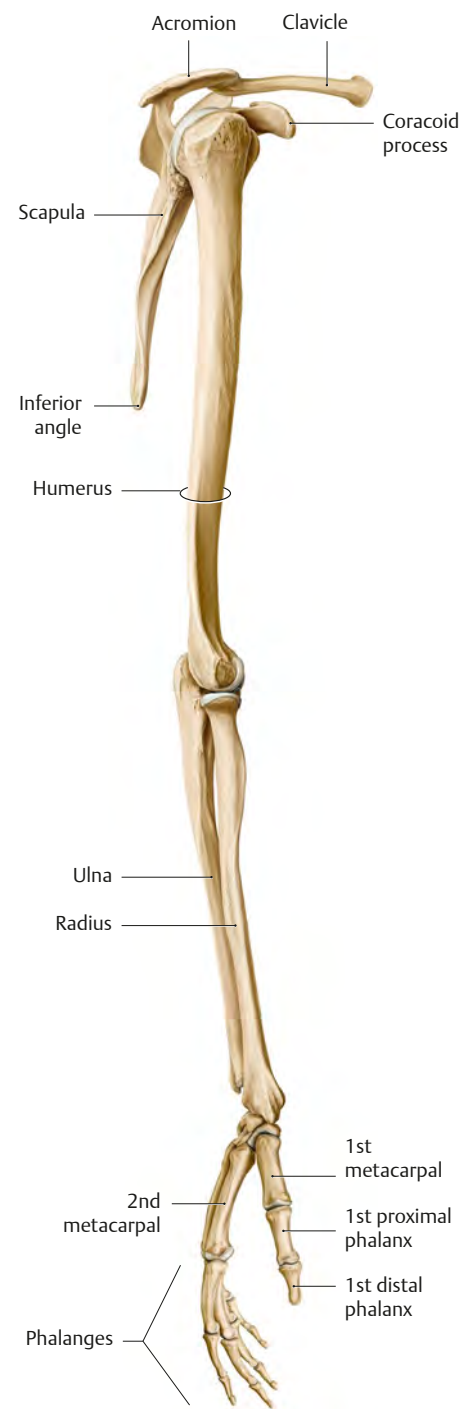
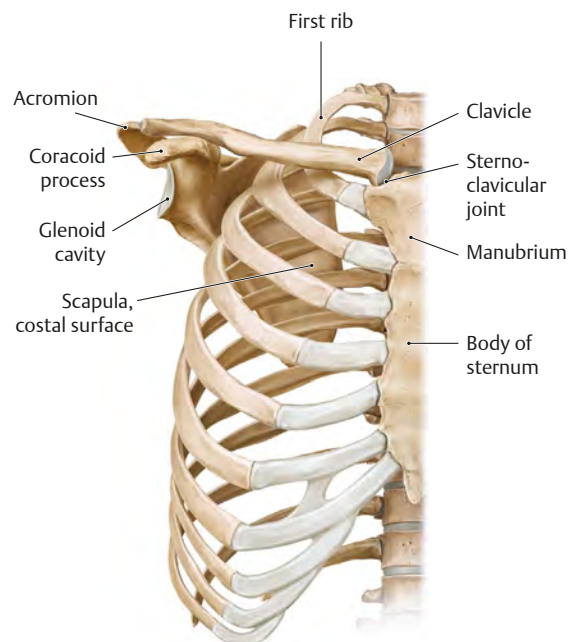


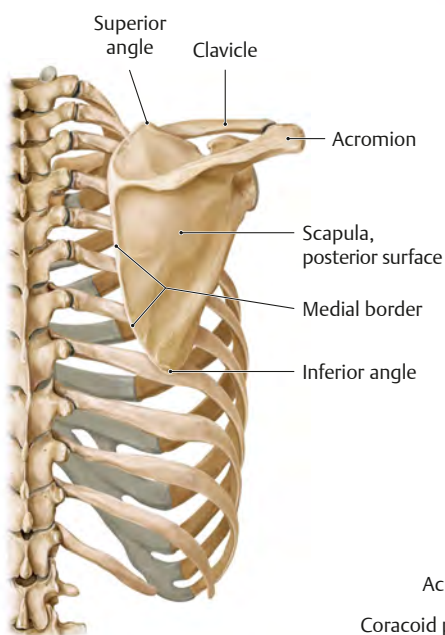
Fig. 25.2 Bones of the shoulder girdle in normal relation to those of the trunk



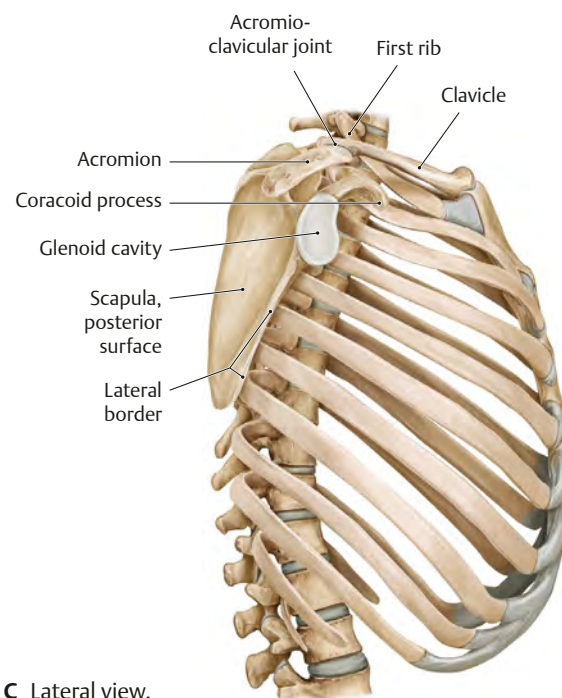
C Lateral view.



A Anterior view.



B Posterior view.



C Lateral view.

Clavicle & Scapula

The shoulder girdle (clavicle and scapula) connects the bones of the upper limb to the thoracic cage. Whereas the pelvic girdle (paired hip bones) is firmly integrated into the axial skeleton (see p. 230), the shoulder girdle is extremely mobile.

Fig. 25.3 Shoulder girdle in situ
Right shoulder, superior view.

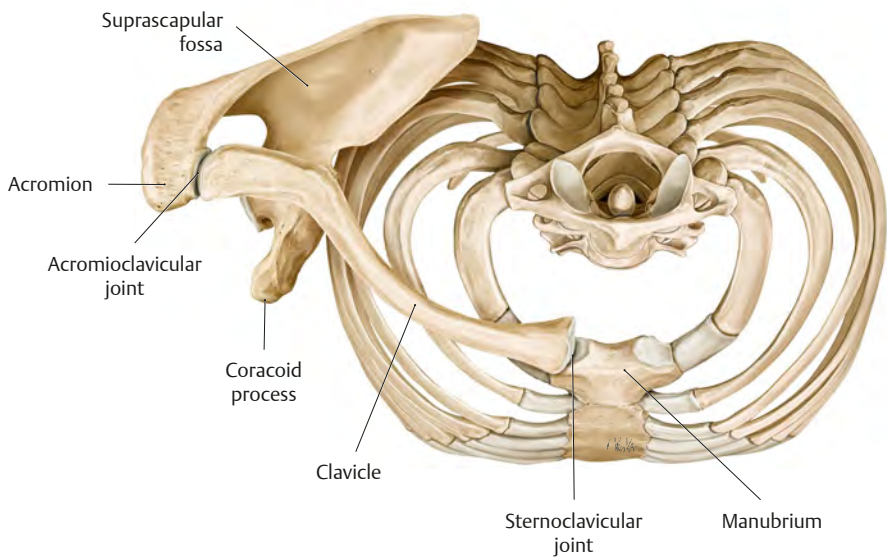
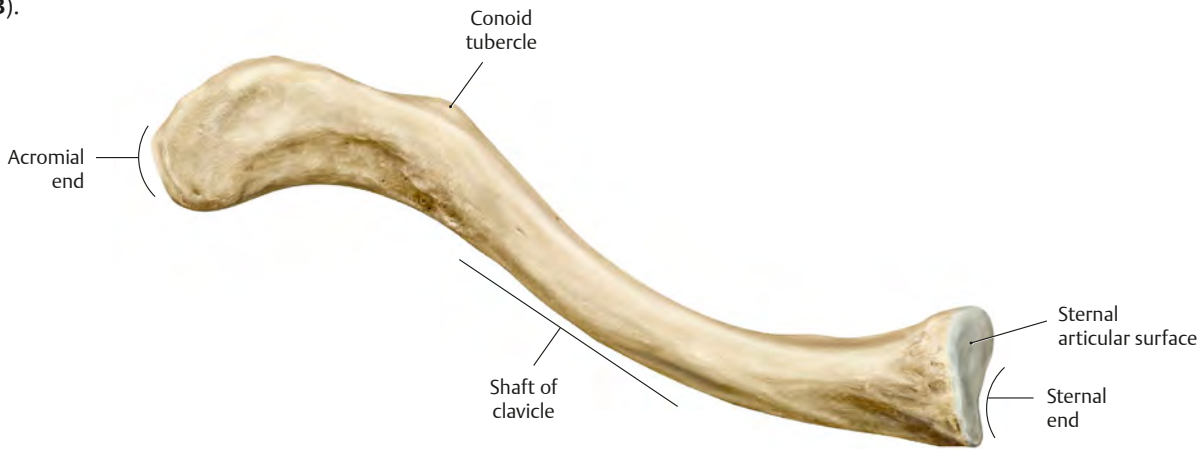
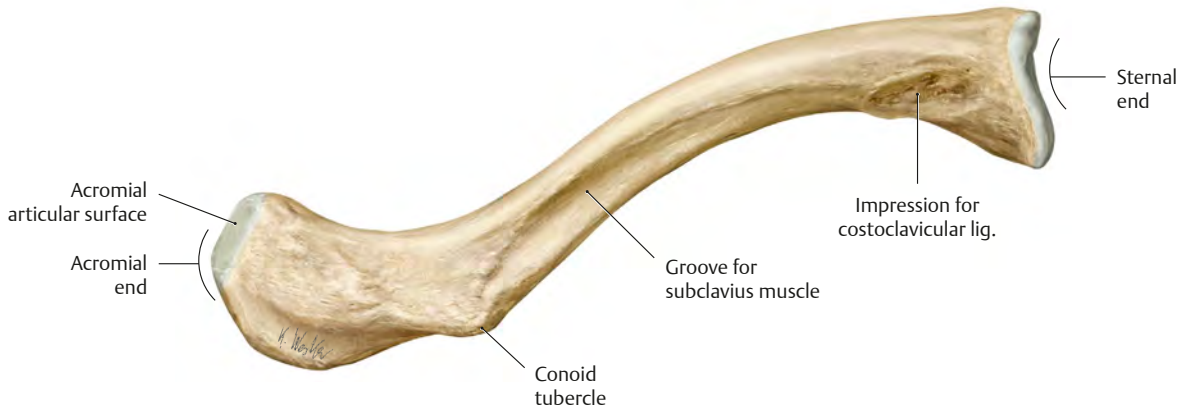


Fig. 25.4 Clavicle

Right clavicle. The S-shaped clavicle is visible and palpable along its entire length (generally 12 to 15 cm). Its medial end articulates with the sternum at the sternoclavicular joint. Its lateral end articulates with the scapula at the acromioclavicular joint (see Fig. 25.3).



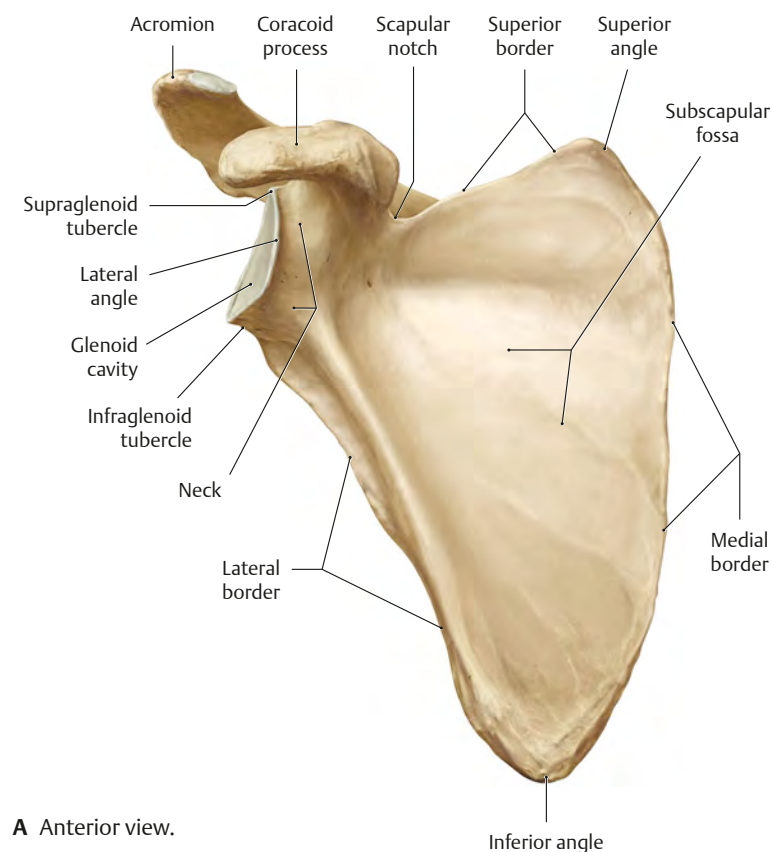
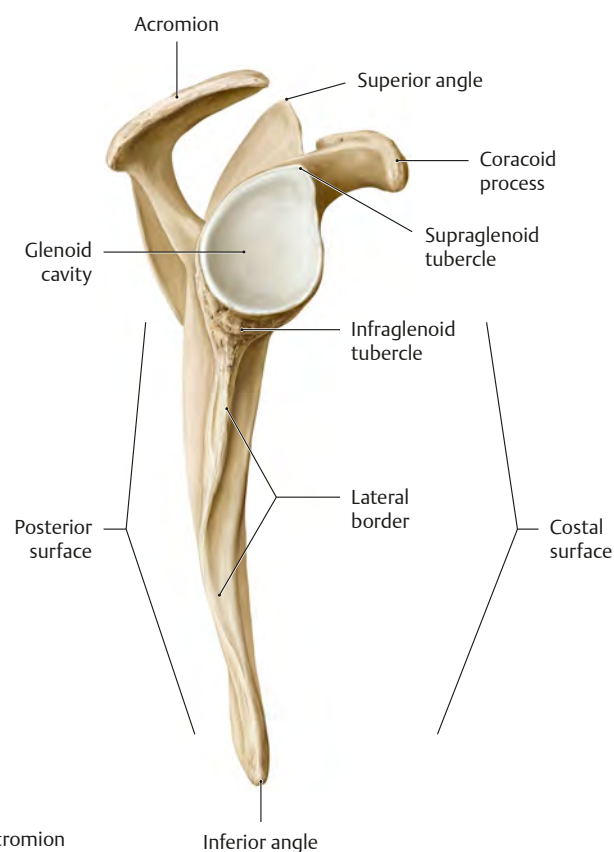
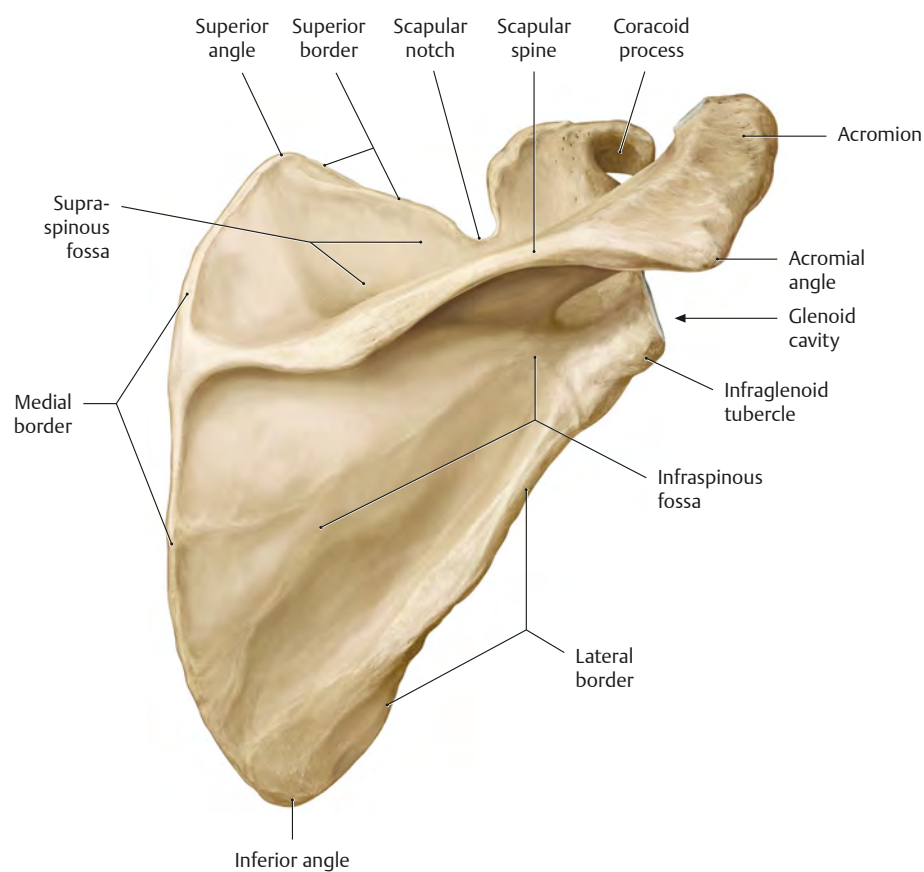
A Superior view.



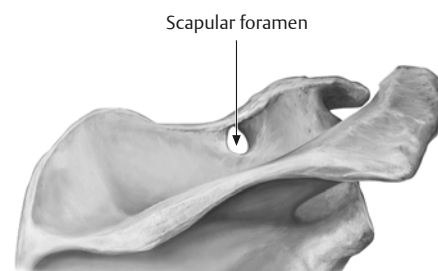
B Inferior view.

Fig. 25.5 Scapula

Right scapula. In its normal anatomical position, the scapula extends from the 2nd to the 7th rib.

**A** Anterior view.**B** Right lateral view.**C** Posterior view.**Clinical box 25.1****Scapular foramen**

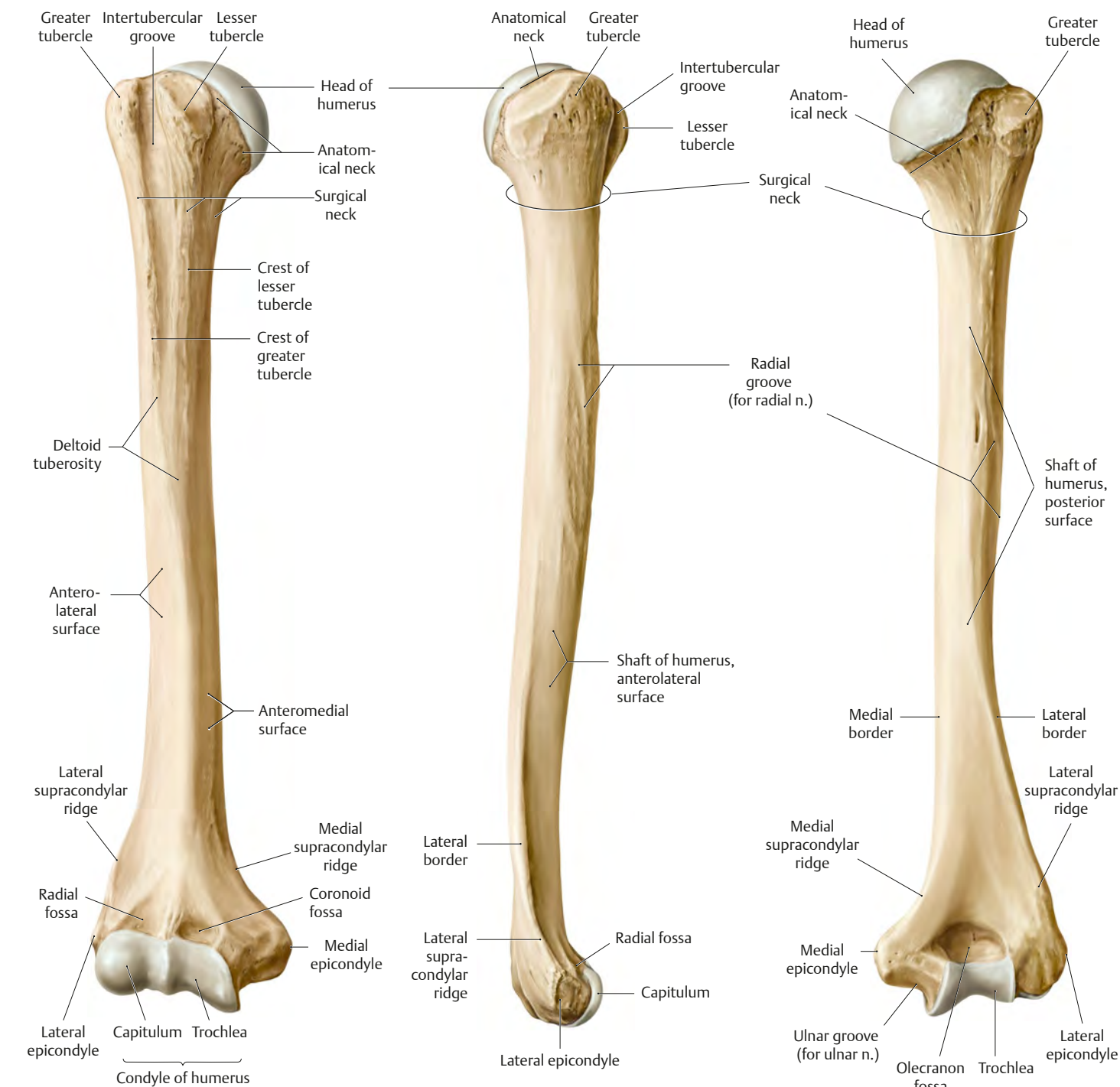
The superior transverse ligament of the scapula (see **Fig. 25.14**) may become ossified, transforming the scapular notch into an anomalous bony canal, the scapular foramen. This can lead to compression of the suprascapular nerve as it passes through the canal (see **p. 381**).



Humerus

Fig. 25.6 Humerus

Right humerus. The head of the humerus articulates with the scapula at the glenohumeral joint (see p. 302). The capitulum and trochlea of the humerus articulate with the radius and ulna, respectively, at the elbow (cubital) joint (see p. 326).



A Anterior view.

B Lateral view.

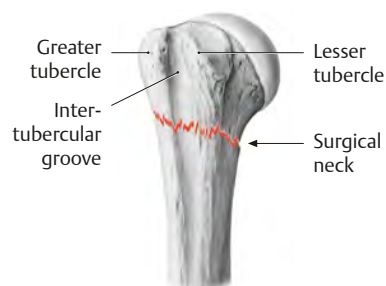
C Posterior view.



Clinical box 25.2

Fractures of the humerus

Anterior view. Fractures of the proximal humerus are very common and occur predominantly in older patients who sustain a fall onto the outstretched arm or directly onto the shoulder. Three main types are distinguished.



A Extra-articular fracture.



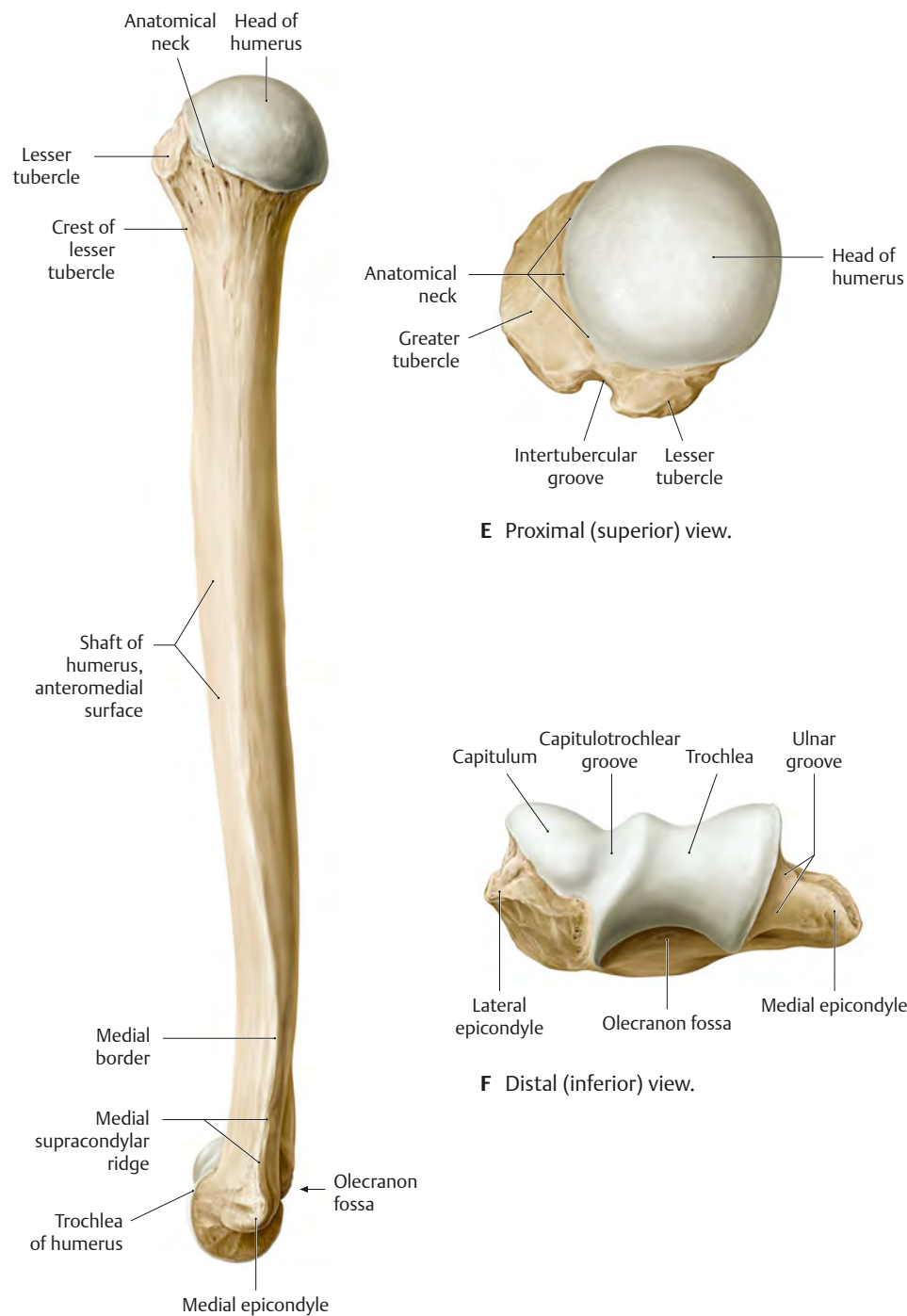
B Intra-articular fracture.



C Comminuted fracture.

Extra-articular fractures and intra-articular fractures are often accompanied by injuries of the blood vessels that supply the humeral head (anterior and posterior circumflex humeral arteries), with an associated risk of post-traumatic avascular necrosis.

Fractures of the surgical neck can damage the axillary nerve and fractures of the humeral shaft and distal humerus are frequently associated with damage to the radial nerve.



D Medial view.

E Proximal (superior) view.

F Distal (inferior) view.

Joints of the Shoulder

Fig. 25.7 Joints of the shoulder: Overview
Right shoulder, anterior view.

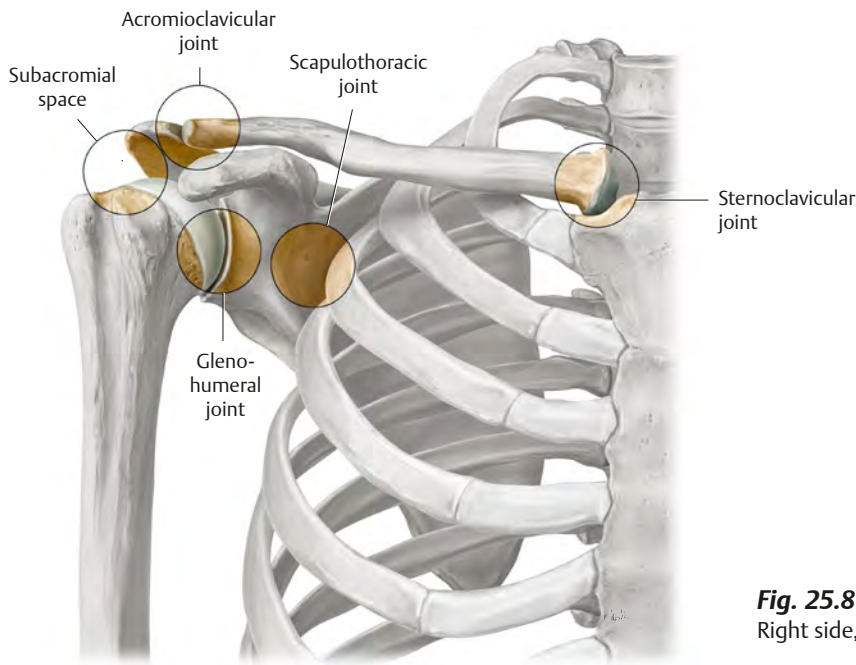


Fig. 25.8 Joints of the shoulder girdle
Right side, superior view.

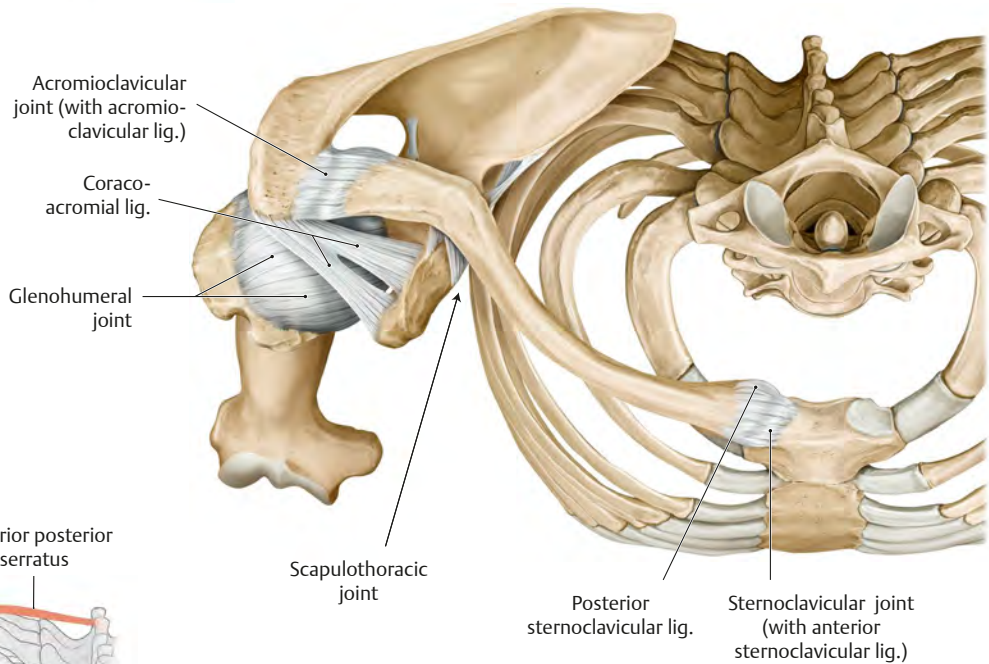


Fig. 25.9 Scapulothoracic joint
Right side, superior view. In all movements of the shoulder girdle, the scapula glides on a curved surface of loose connective tissue between the serratus anterior and the subscapularis muscles. This surface can be considered a scapulothoracic joint.

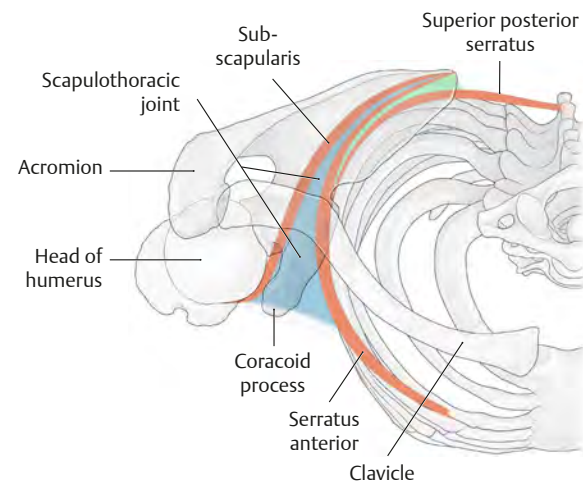
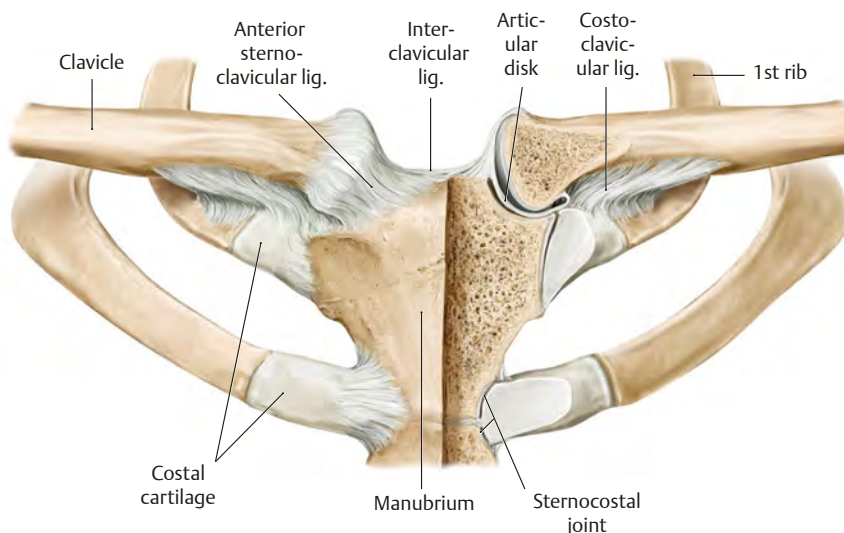
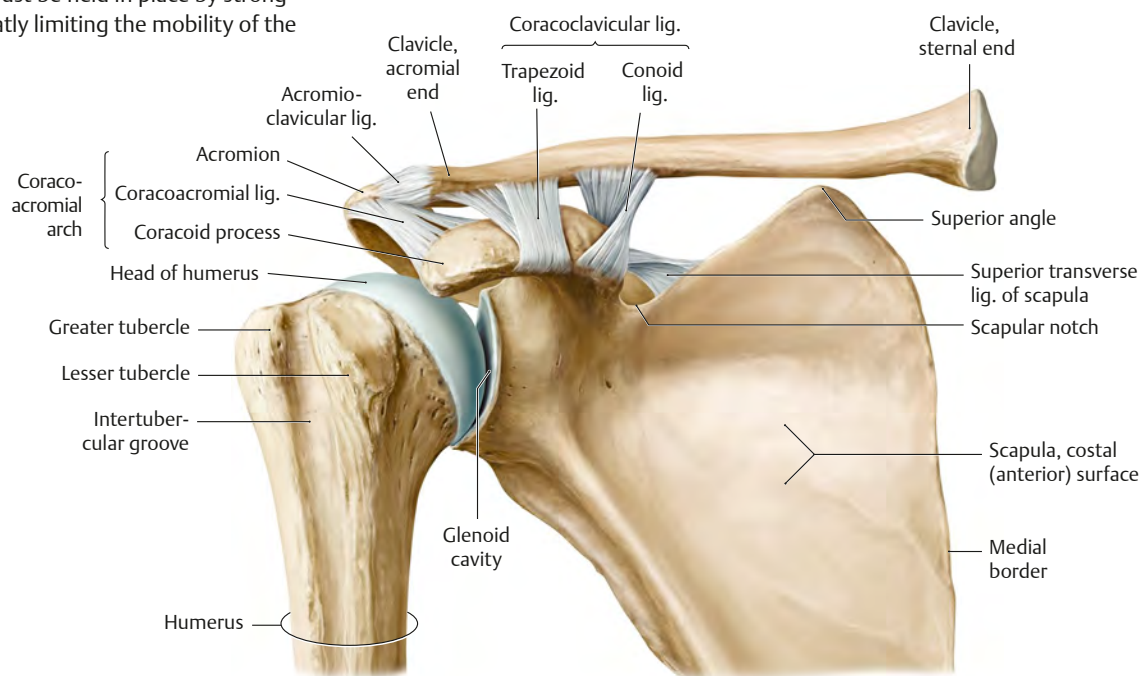


Fig. 25.10 Sternoclavicular joint

Anterior view with sternum coronally sectioned (left). *Note:* A fibrocartilaginous articular disk compensates for the mismatch of surfaces between the two saddle-shaped articular facets of the clavicle and the manubrium.

**Fig. 25.11 Acromioclavicular joint**

Anterior view. The acromioclavicular joint is a plane joint. Because the articulating surfaces are flat, they must be held in place by strong ligaments, greatly limiting the mobility of the joint.

**Clinical box 25.3****Injuries of the acromioclavicular joint**

A fall onto the outstretched arm or shoulder frequently causes dislocation of the acromioclavicular joint (often known as a “shoulder separation”) and damage to the coracoclavicular ligaments.



A Stretching of acromioclavicular ligaments.



B Rupture of acromioclavicular ligament.

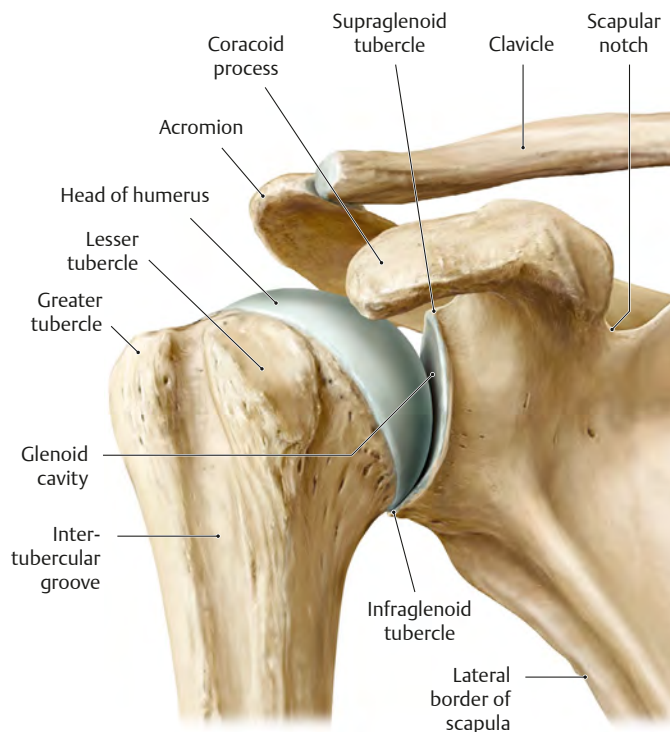


C Complete dislocation of acromioclavicular joint. Note rupture of acromioclavicular and coracoclavicular ligaments.

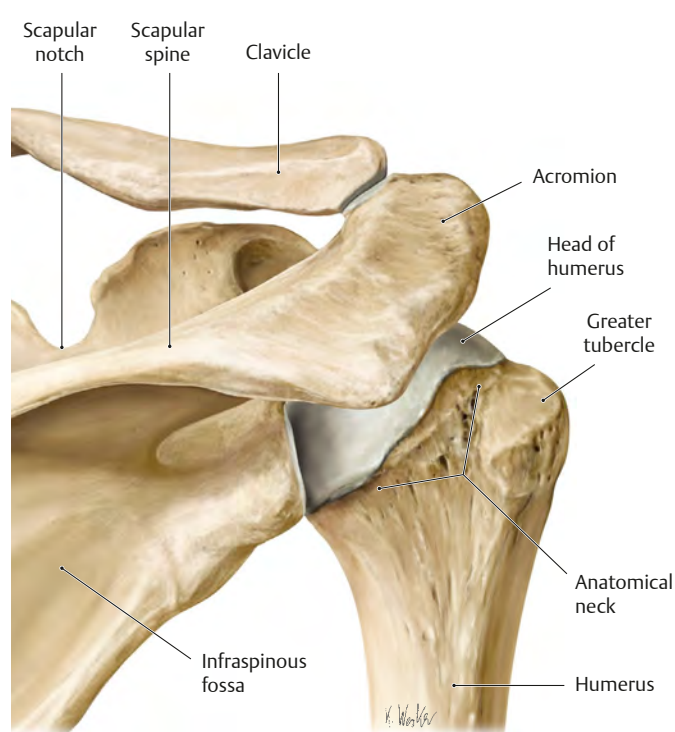
Joints of the Shoulder: Glenohumeral Joint

Upper Limb

Fig. 25.12 Glenohumeral joint: Bony elements
Right shoulder.

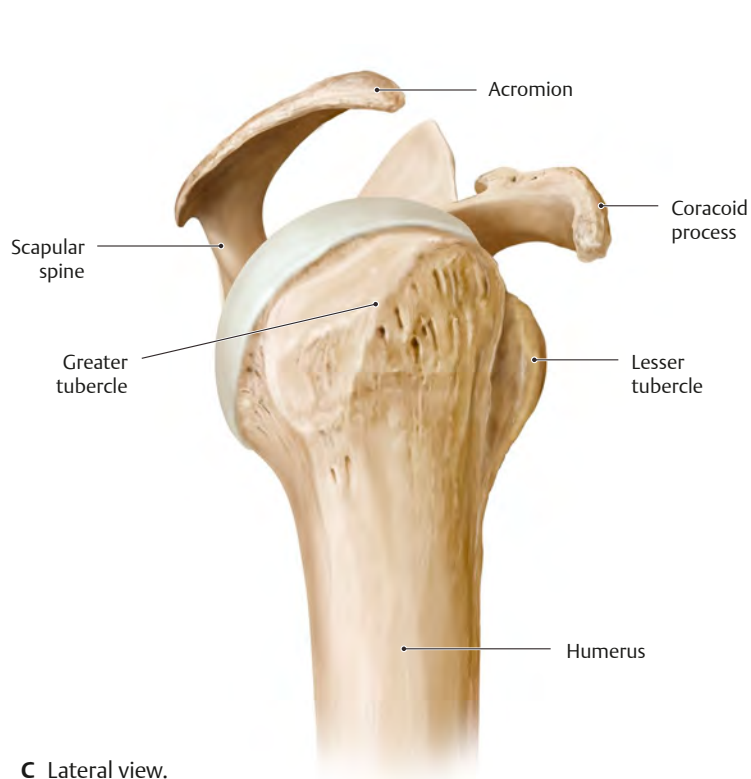


A Anterior view.



B Posterior view.

Fig. 25.13 Glenohumeral joint cavity



C Lateral view.

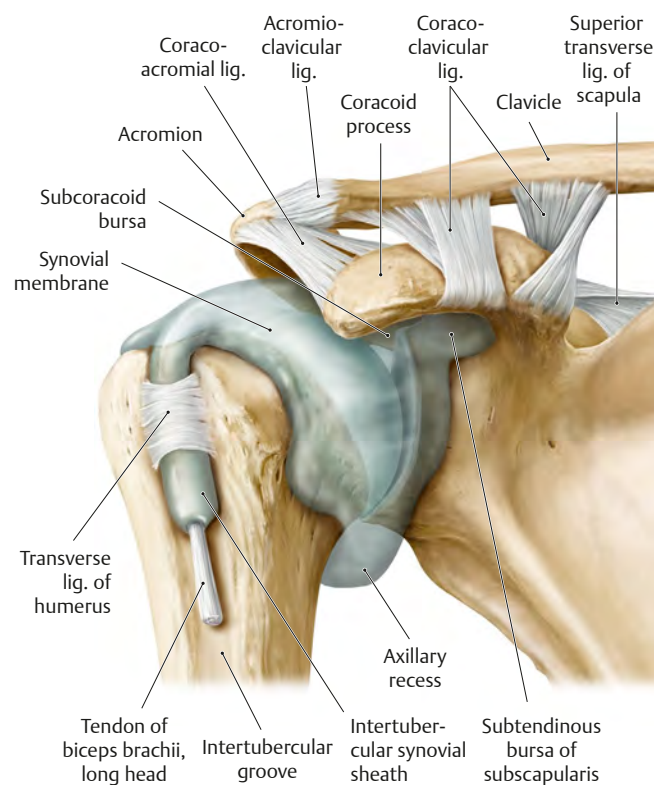
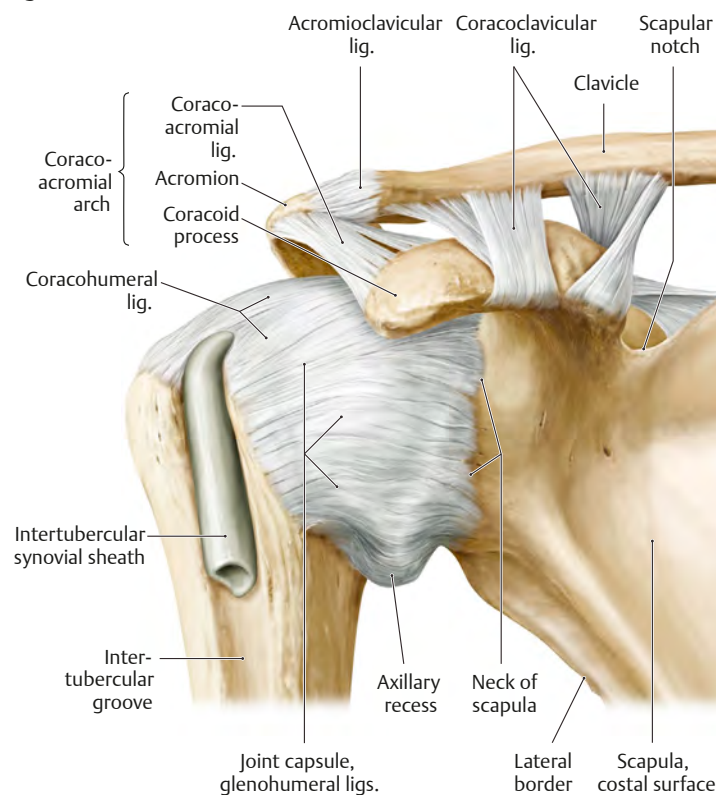
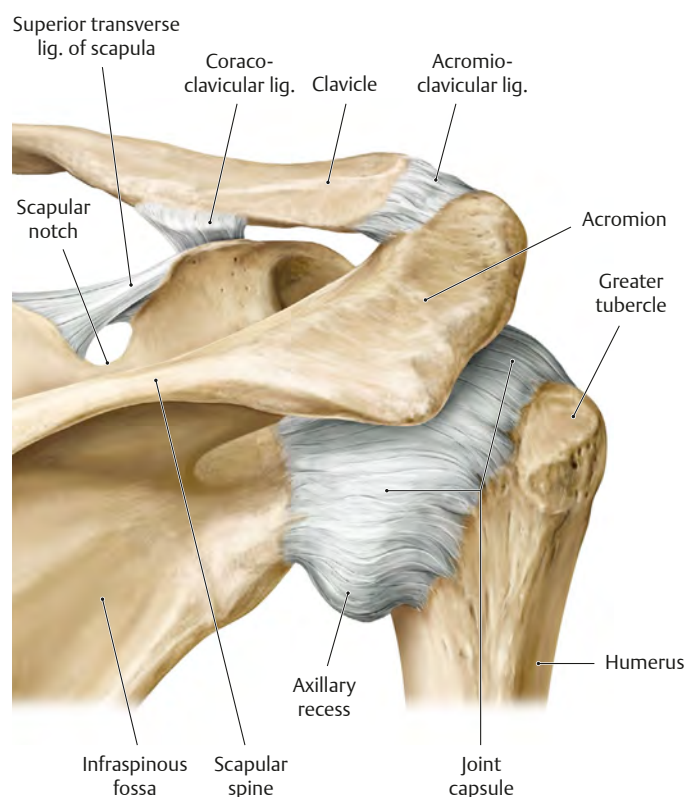


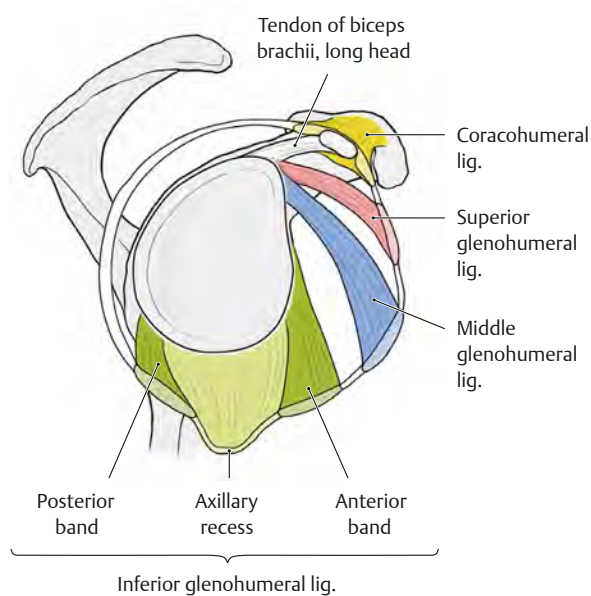
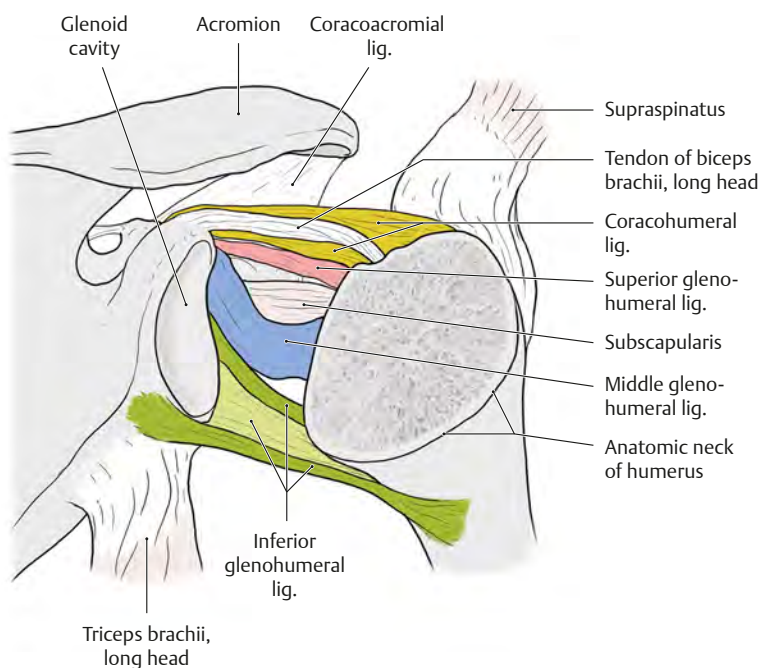
Fig. 25.14 Glenohumeral joint: Capsule and ligaments

Right shoulder.

**A** Anterior view.**B** Posterior view.**Fig. 25.15 Ligaments reinforcing capsule**

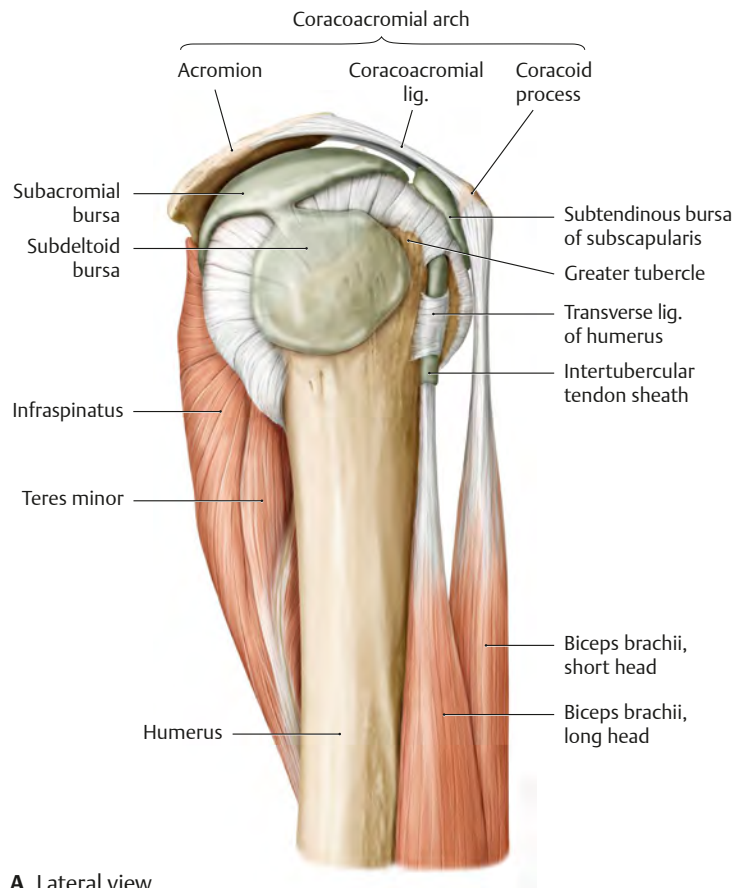
Schematic representation of the ligaments reinforcing the capsule after removal of the humeral head.

Right shoulder.

**A** Lateral view.**B** Posterior view.

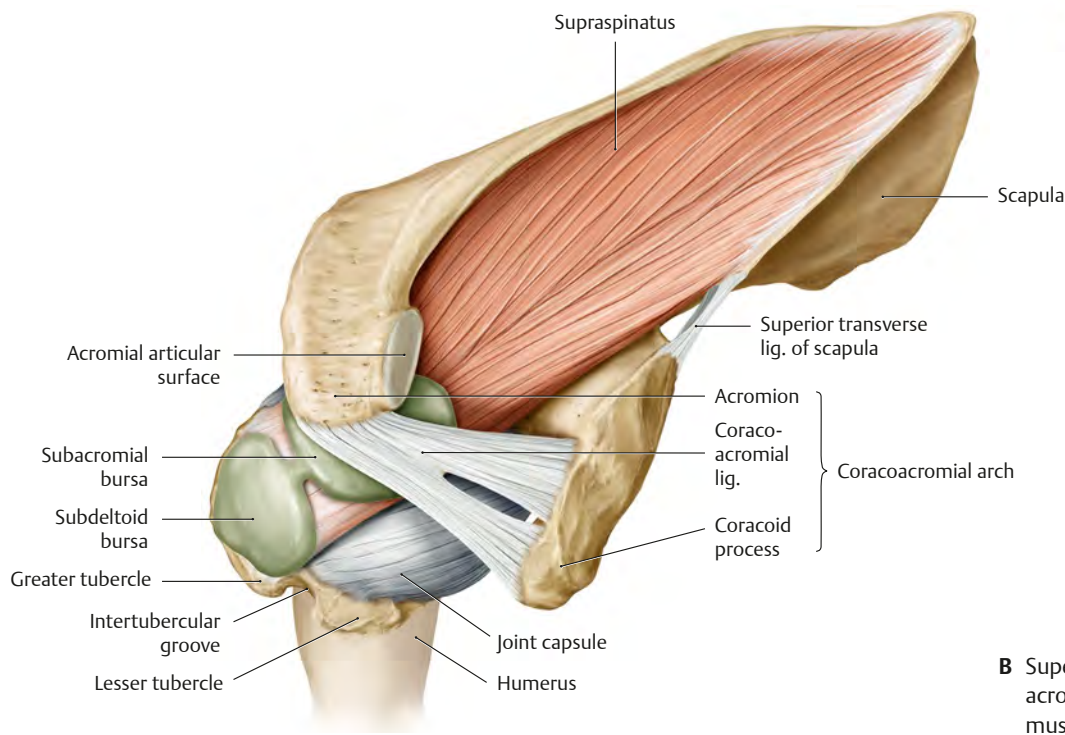
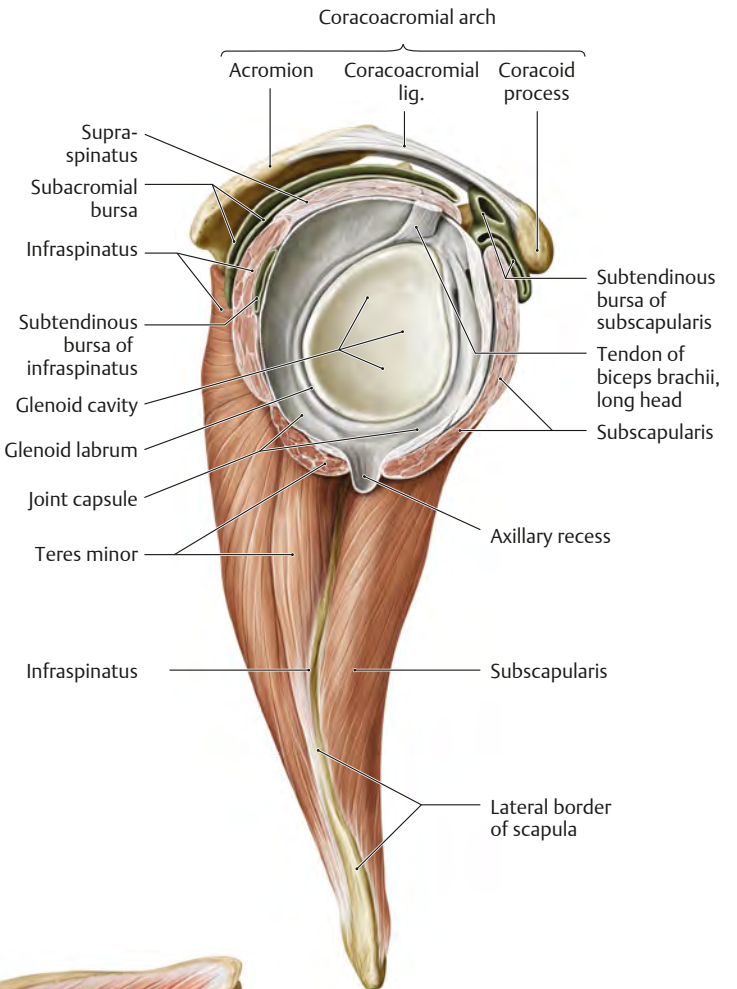
Subacromial Space & Bursae

Fig. 25.16 Subacromial space
Right shoulder.



A Lateral view.

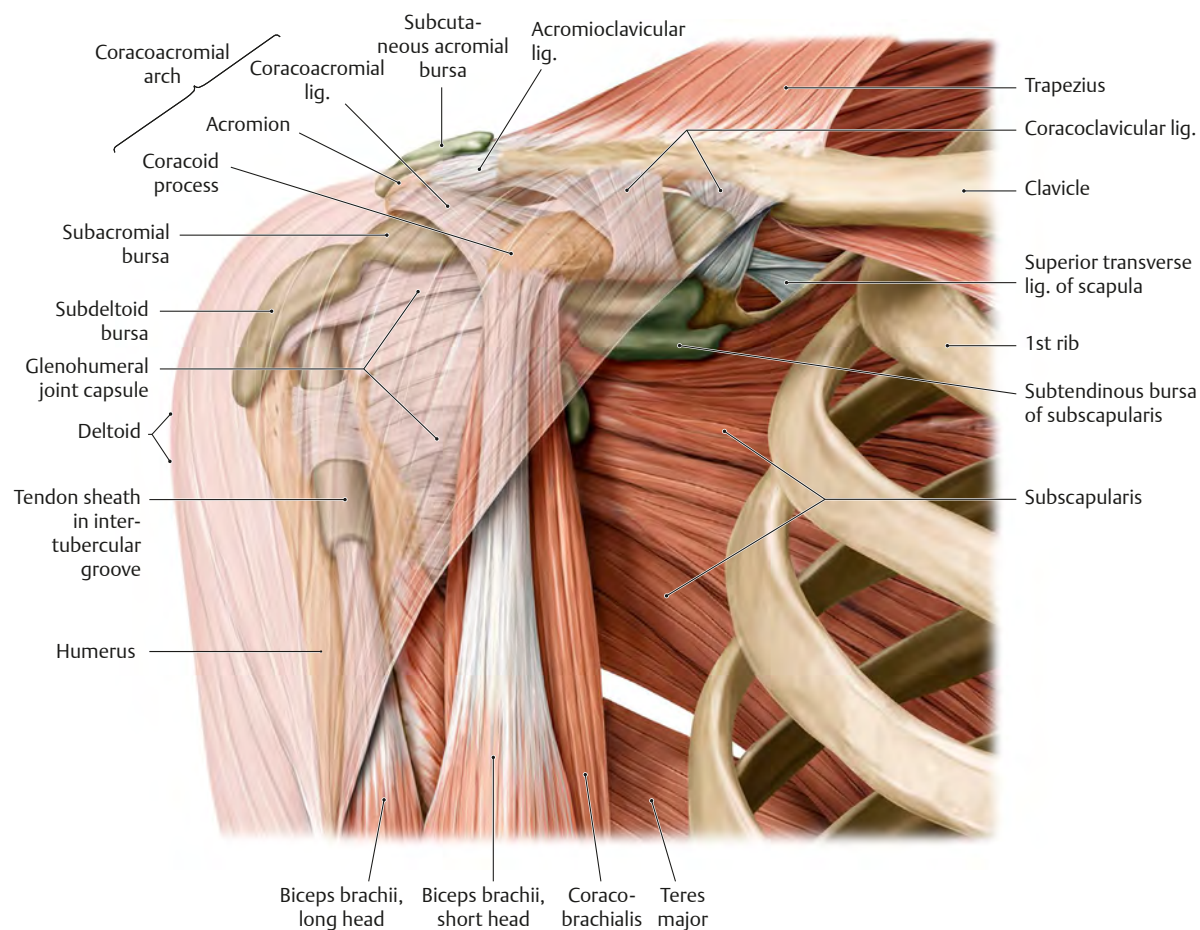
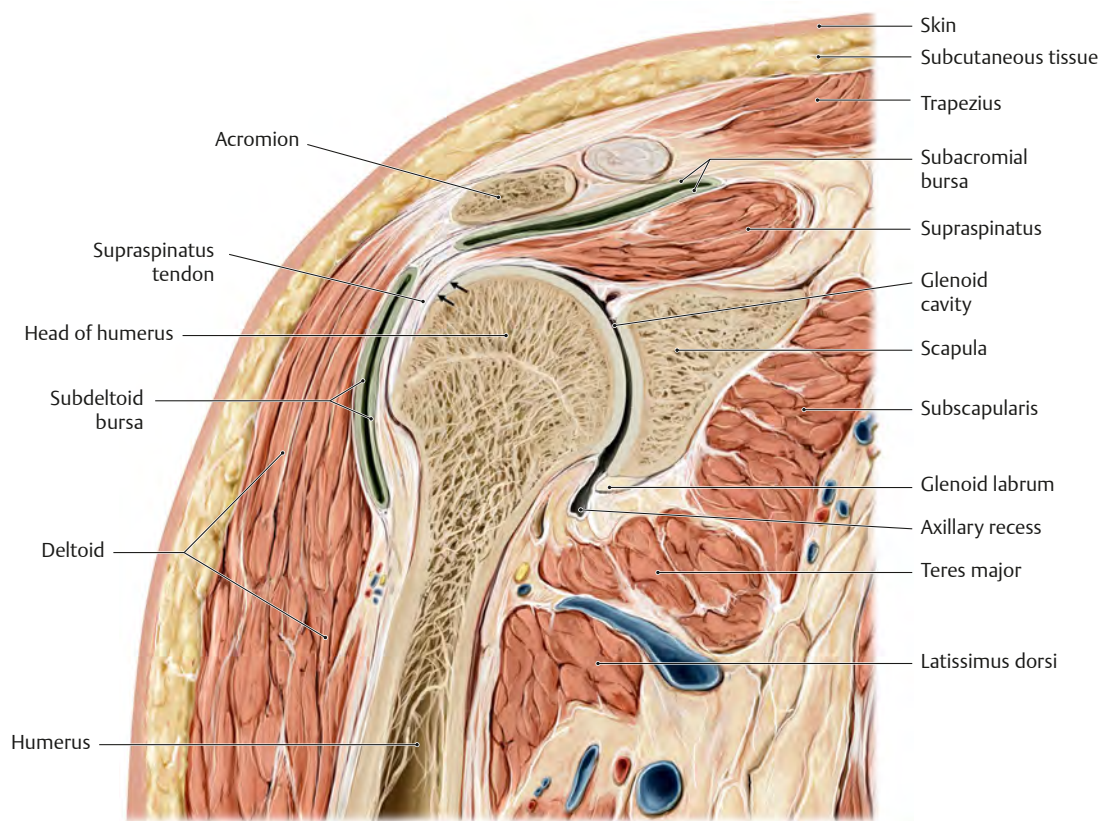
Fig. 25.17 Subacromial bursa and glenoid cavity
Right shoulder, lateral view of sagittal section with humerus removed.



B Superior view. Note the position of the subacromial bursa between the supraspinatus muscle and the coracoacromial arch.

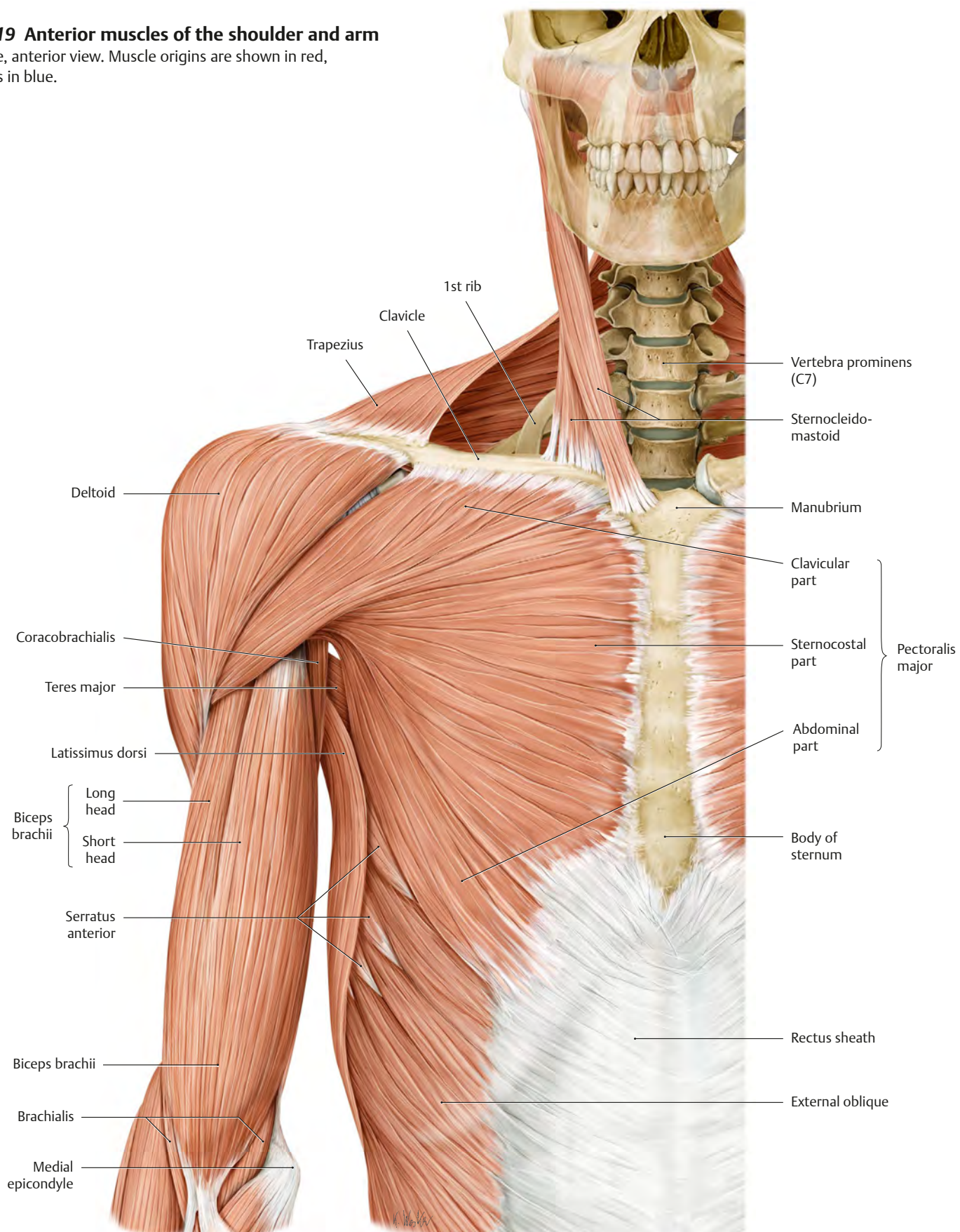
Fig. 25.18 Subacromial and subdeltoid bursae

Right shoulder, anterior view.

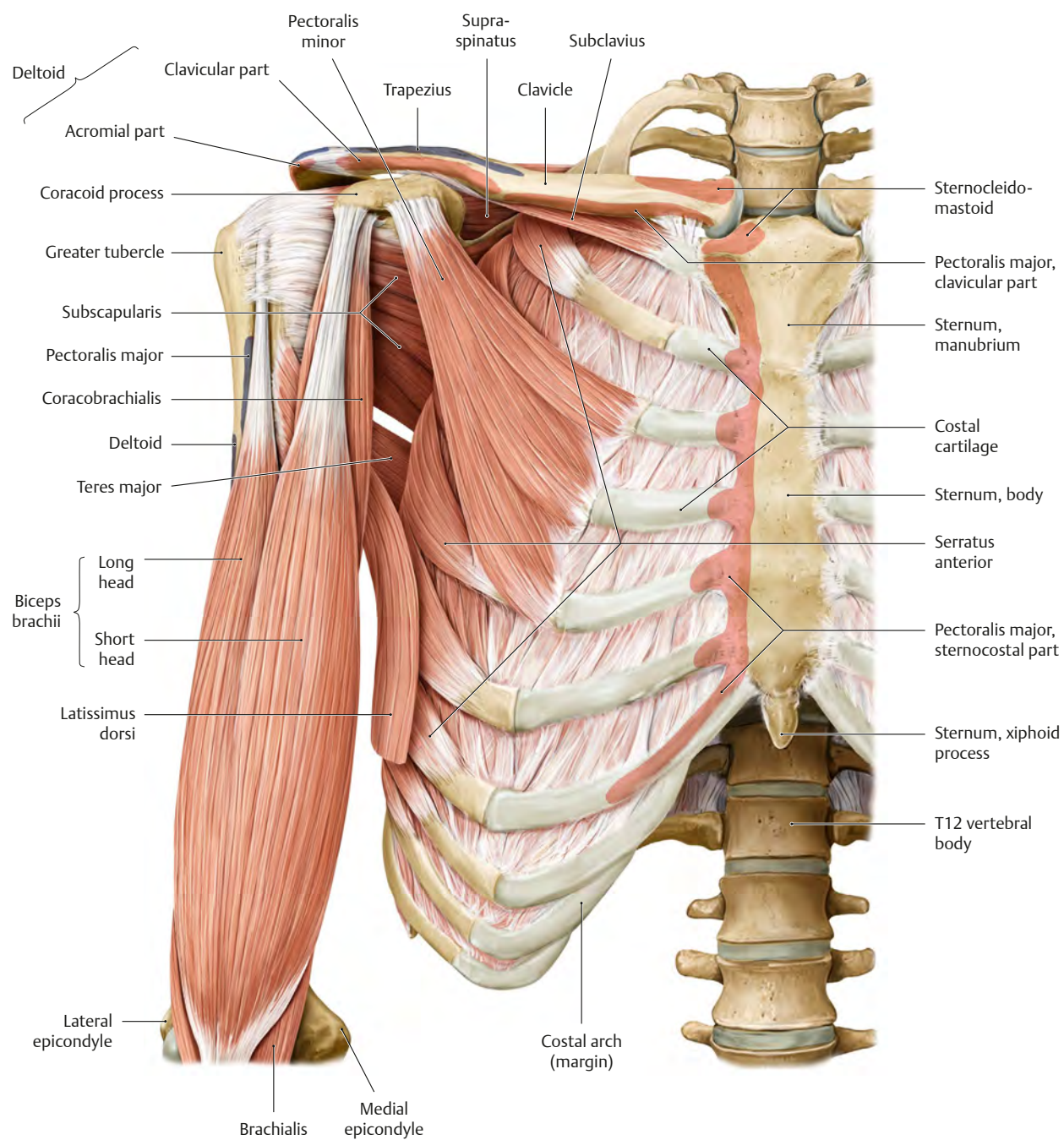
**A** Location of bursae.**B** Coronal section. The arrows are pointing at the supraspinatus tendon, which is frequently injured in a "rotator cuff tear" (for rotator cuff, see p. 317).

Anterior Muscles of the Shoulder & Arm (I)

Fig. 25.19 Anterior muscles of the shoulder and arm
Right side, anterior view. Muscle origins are shown in red, insertions in blue.



A Superficial dissection.

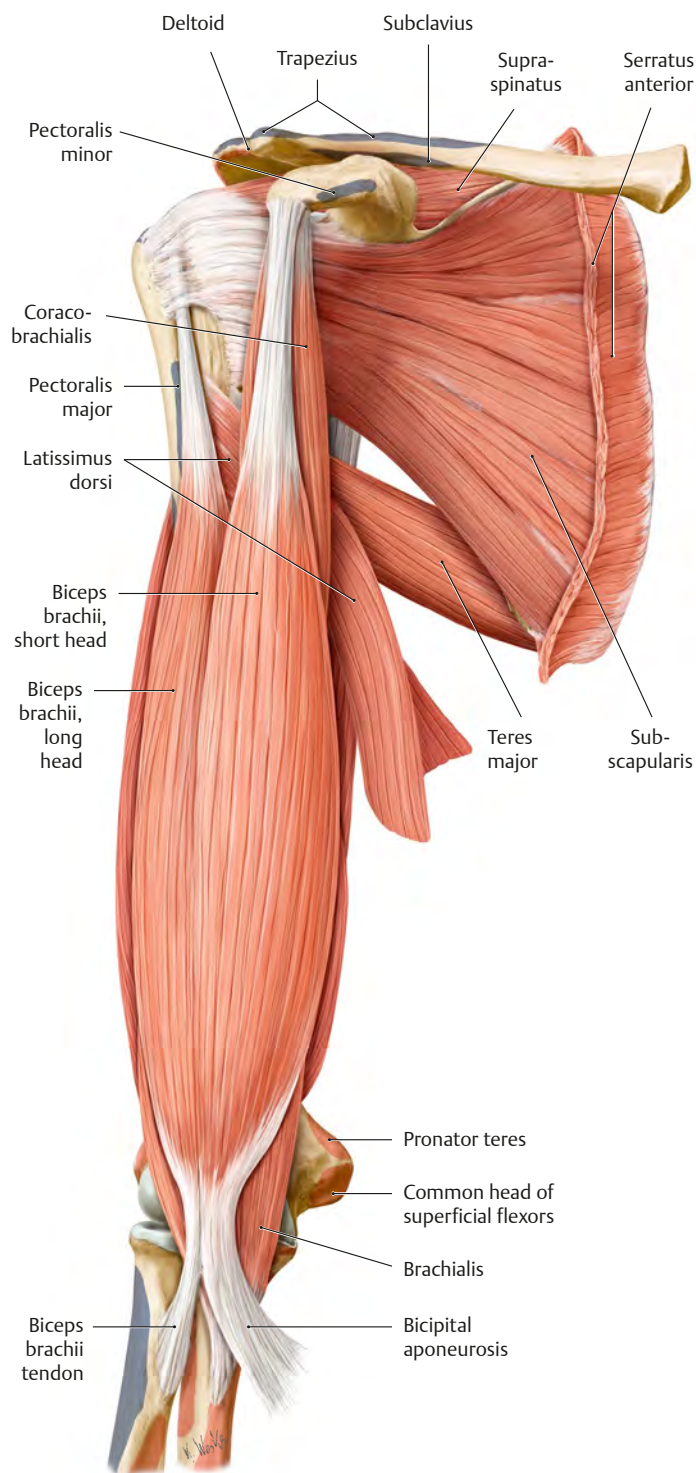


B Deep dissection. *Removed:* Sternocleidomastoid, trapezius, pectoralis major, deltoid, and external oblique muscles.

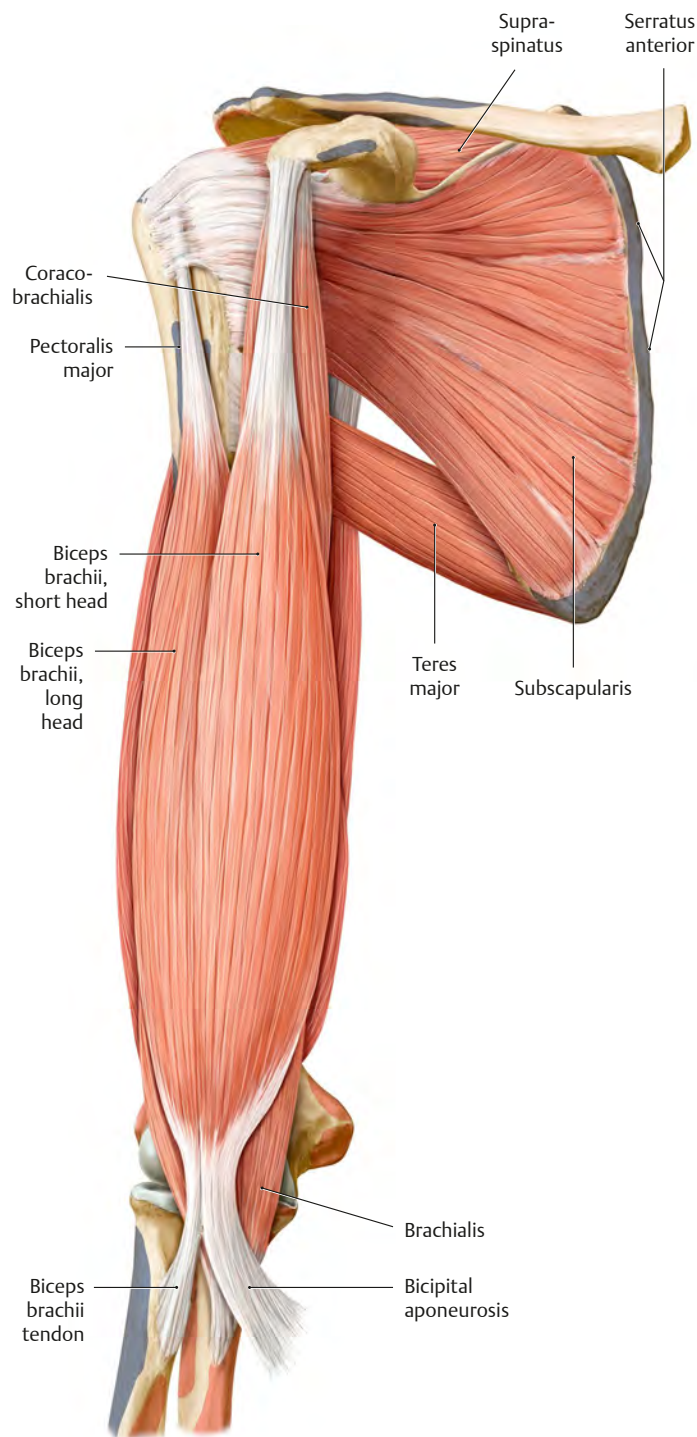
Anterior Muscles of the Shoulder & Arm (II)

Fig. 25.20 Anterior muscles of the shoulder and arm: Dissection

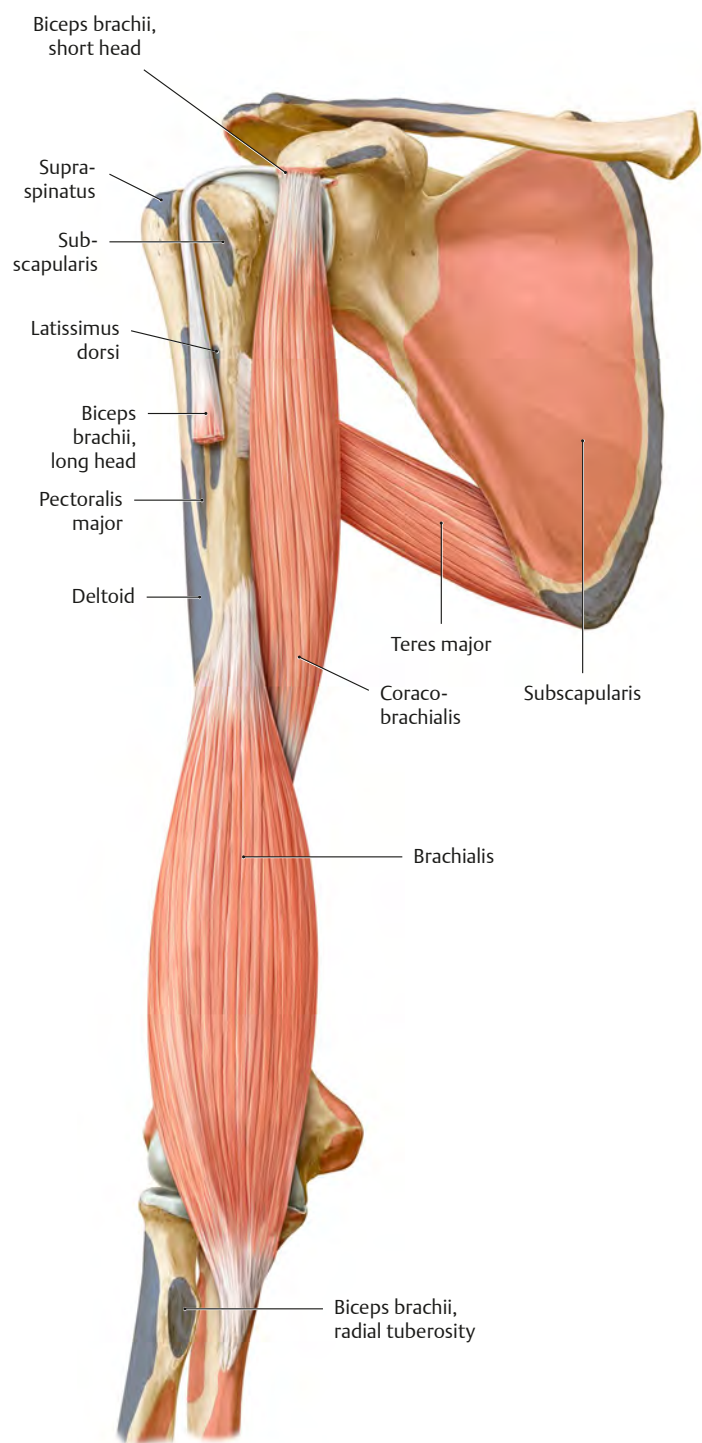
Right arm, anterior view. Muscle origins are shown in red, insertions in blue.



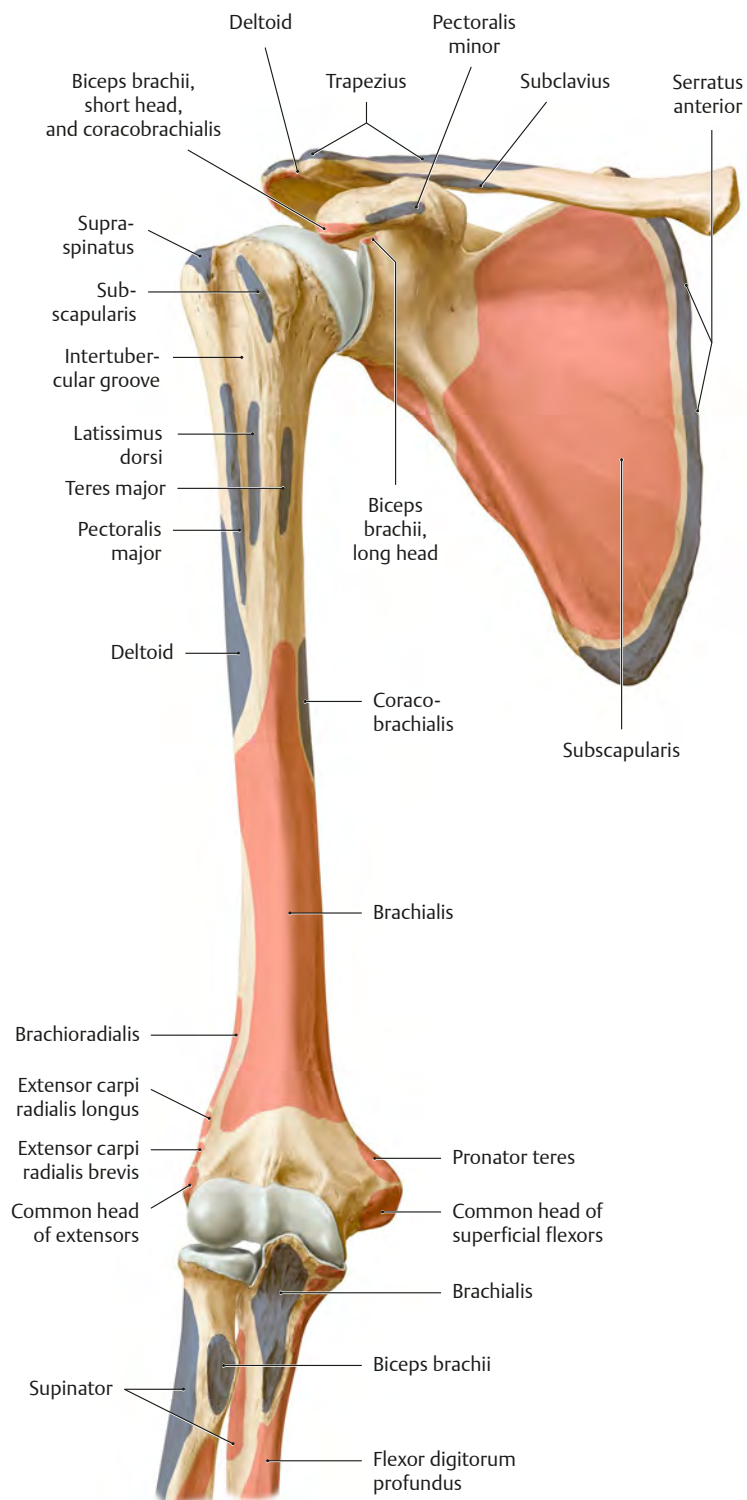
A Removed: Thoracic skeleton. Partially removed: Latissimus dorsi and serratus anterior.



B Removed: Latissimus dorsi and serratus anterior.



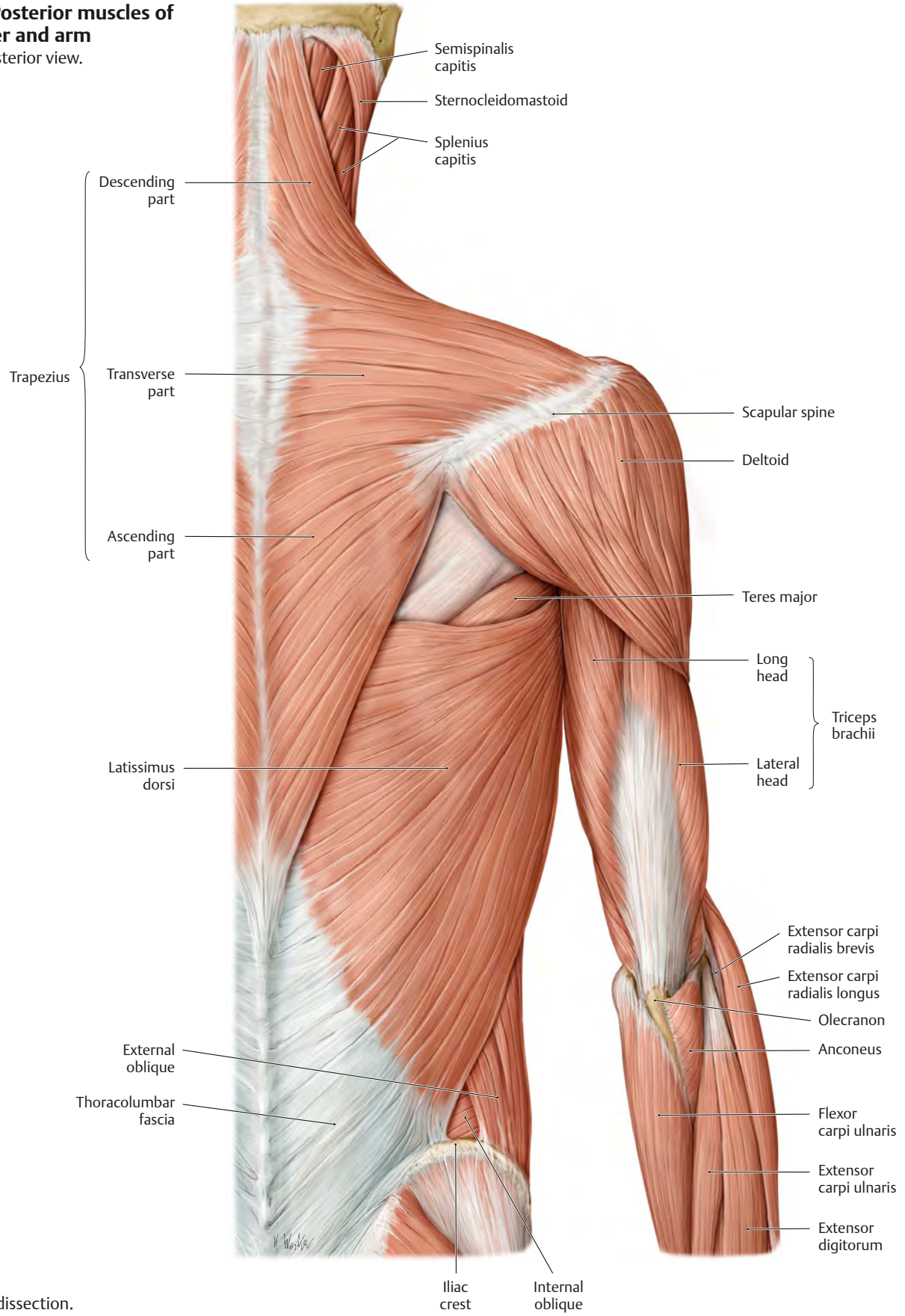
C Removed: Subscapularis and supraspinatus. Partially removed: Biceps brachii.



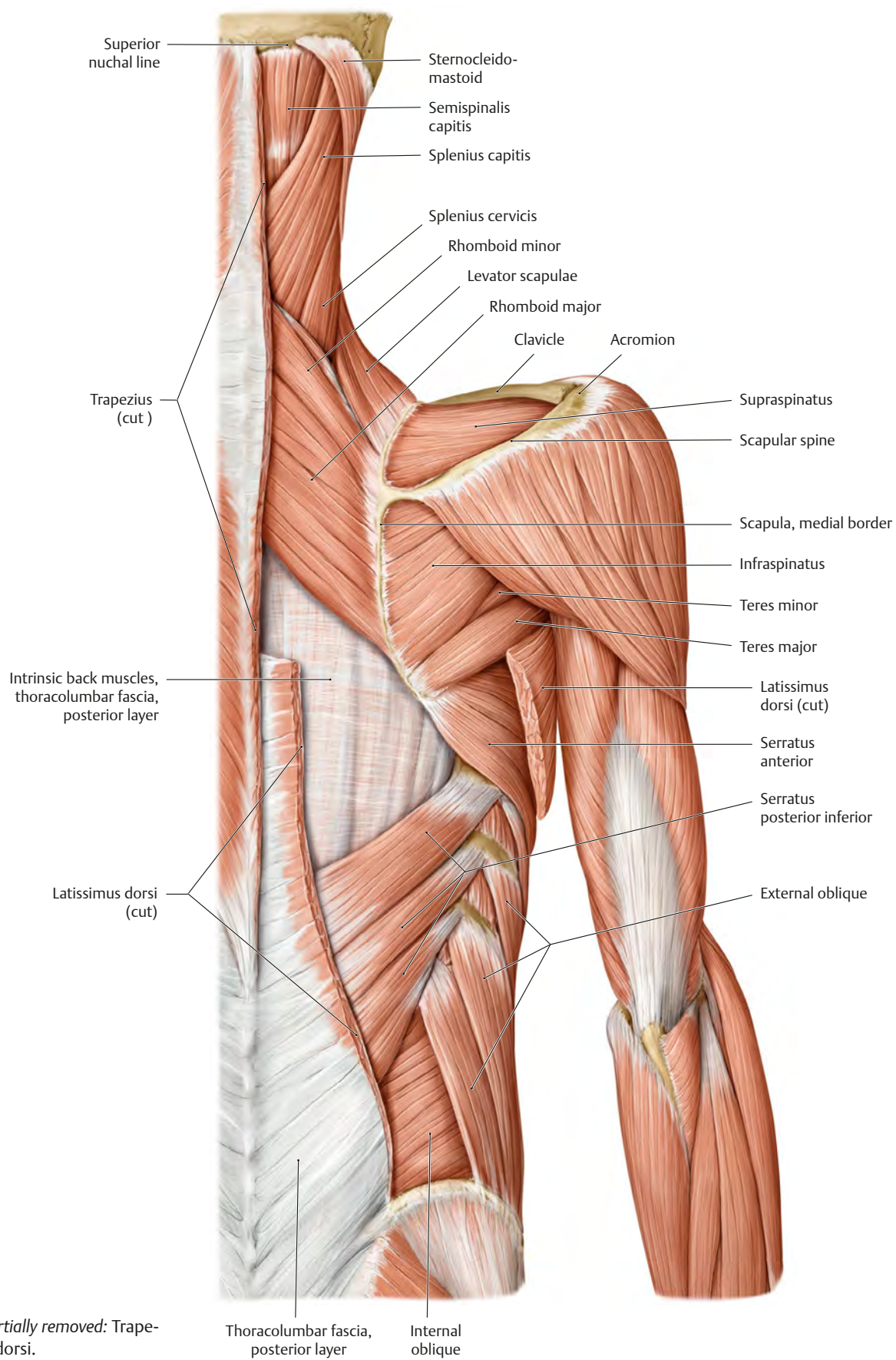
D Removed: Biceps brachii, coracobrachialis, and teres major.

Posterior Muscles of the Shoulder & Arm (I)

Fig. 25.21 Posterior muscles of the shoulder and arm
Right side, posterior view.



A Superficial dissection.

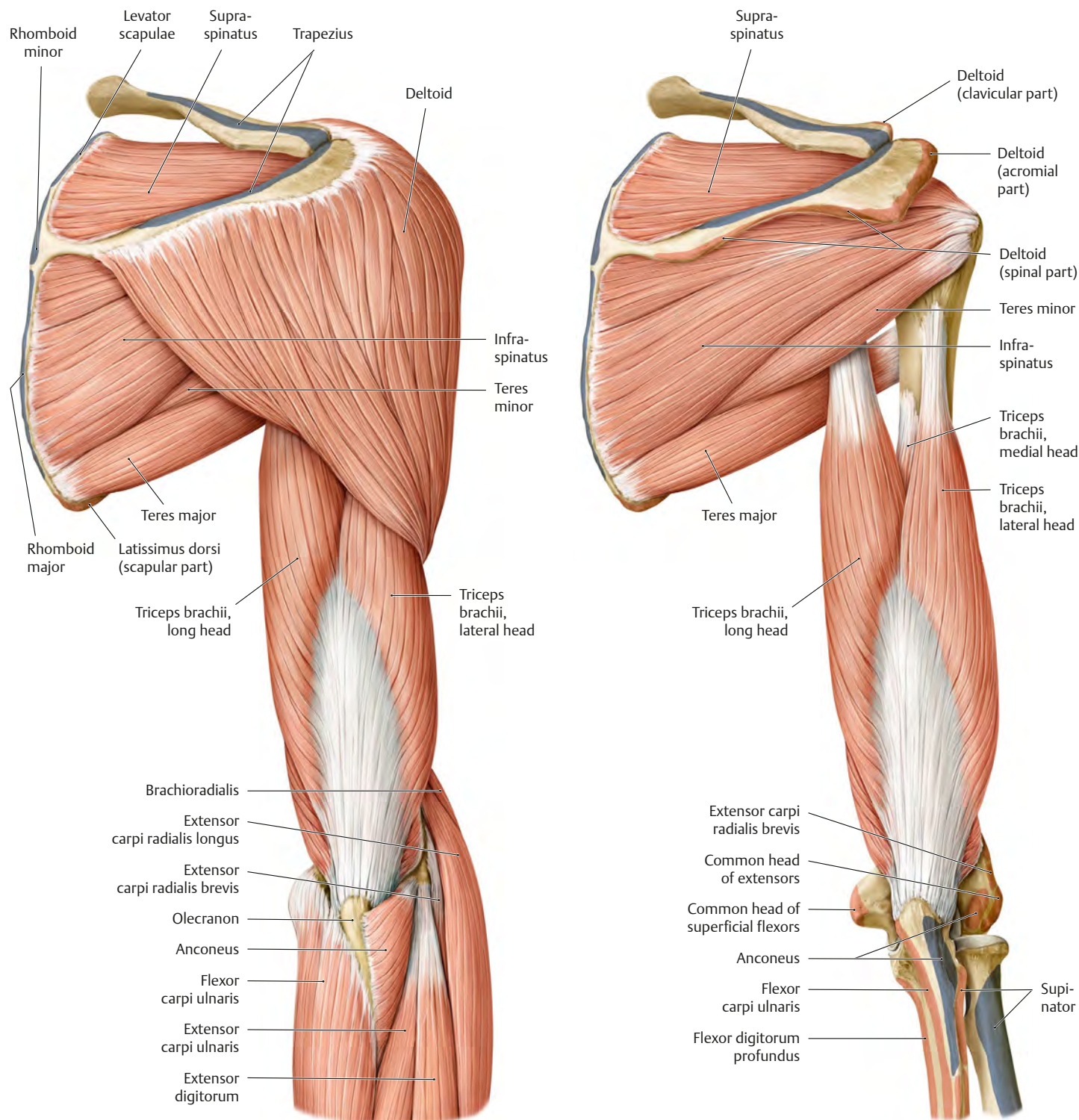


B Deep dissection. *Partially removed:* Trapezius and latissimus dorsi.

Posterior Muscles of the Shoulder & Arm (II)

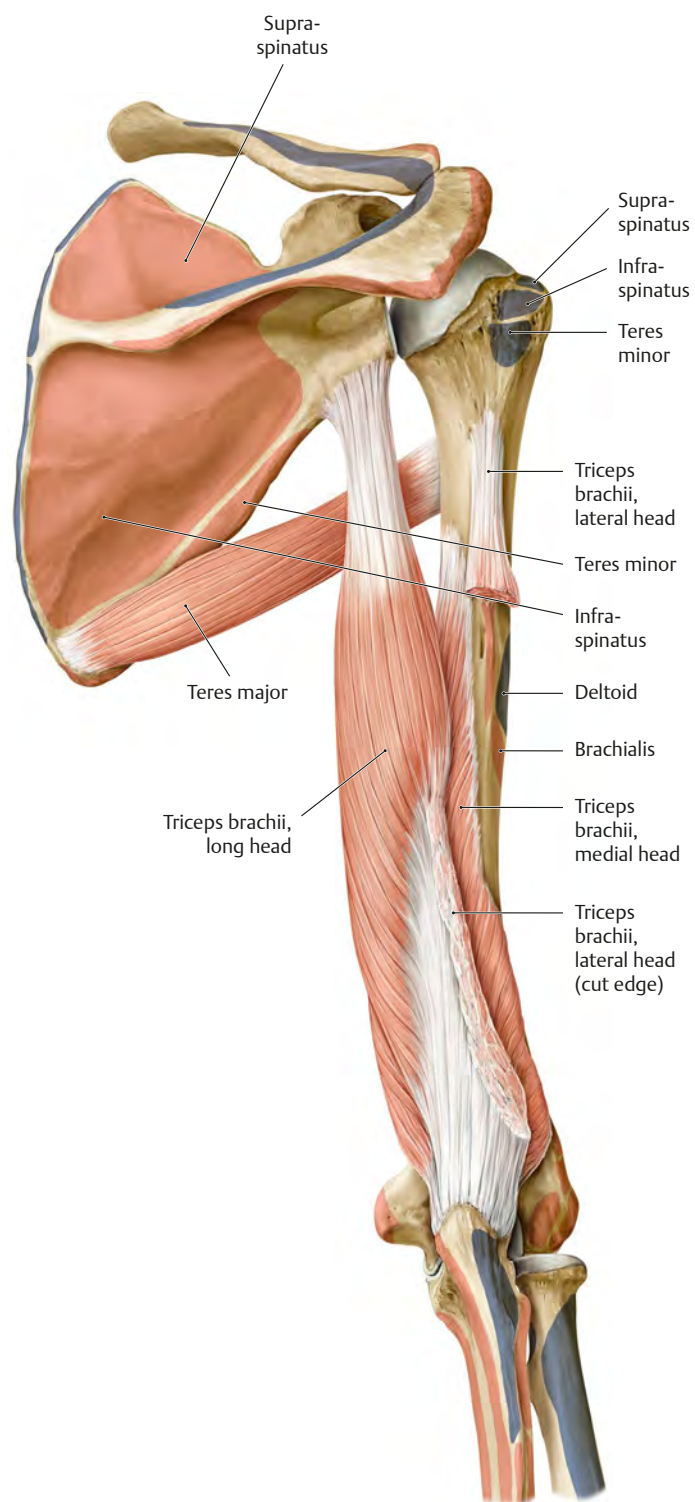
Fig. 25.22 Posterior muscles of the shoulder and arm: Dissection

Right arm, posterior view. Muscle origins are shown in red, insertions in blue.

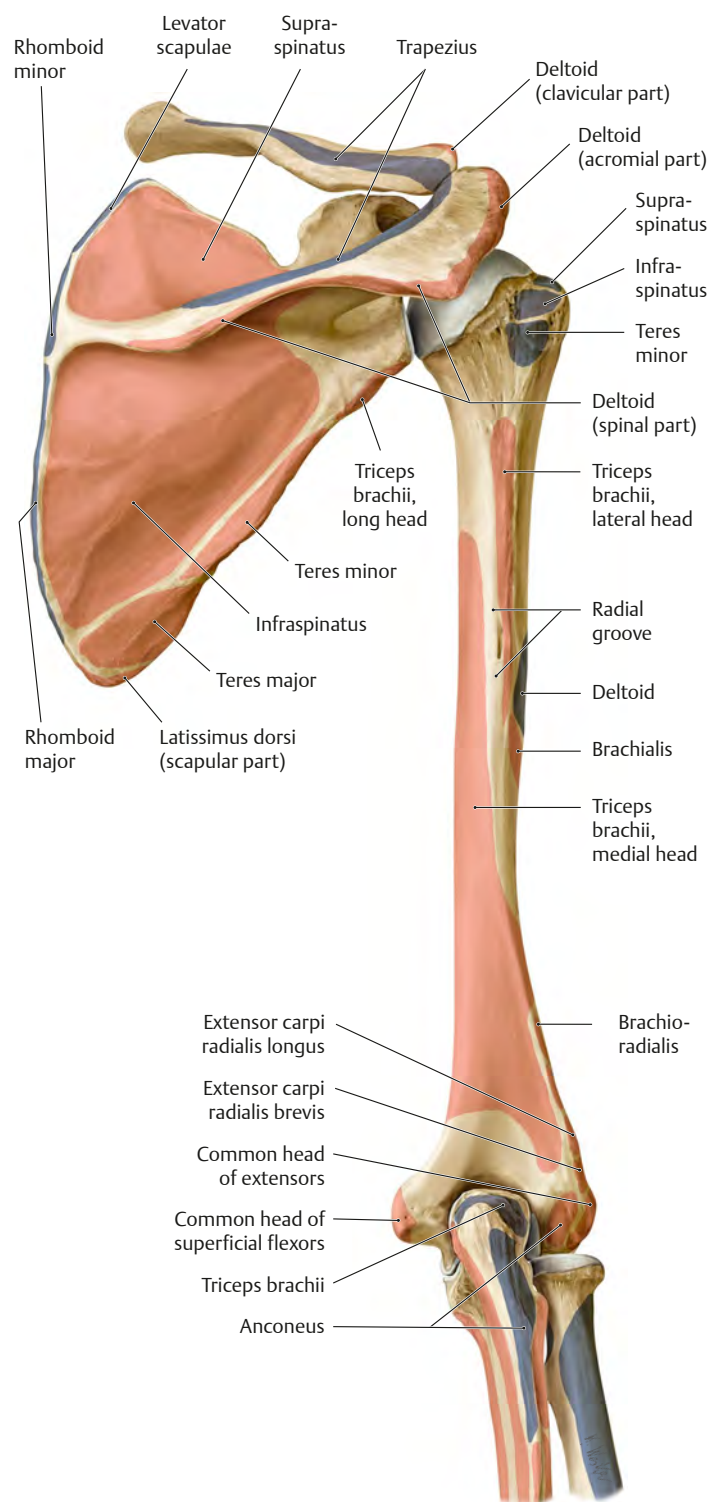


A Removed: Rhomboids major and minor, serratus anterior, and levator scapulae.

B Removed: Deltoid and forearm muscles.



C Removed: Supraspinatus, infraspinatus, and teres minor. Partially removed: Triceps brachii.



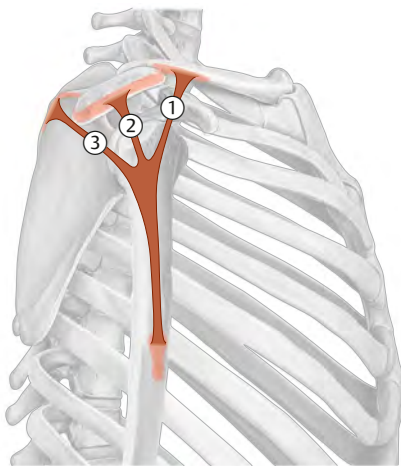
D Removed: Triceps brachii and teres major.

Muscle Facts (I)

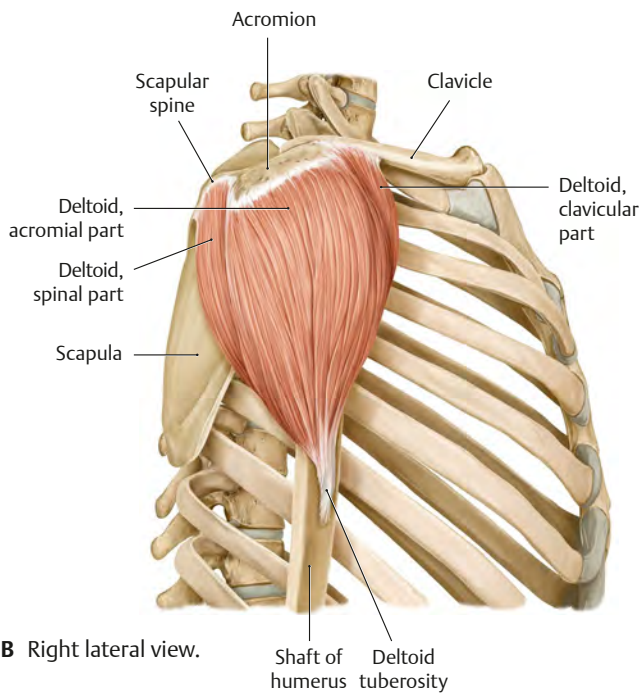
The actions of the three parts of the deltoid muscle depend on their relationship to the position of the humerus and its axis of motion. At less than 60 degrees, the muscles act as adductors, but at greater than

60 degrees, they act as abductors. As a result, the parts of the deltoid can act antagonistically as well as synergistically.

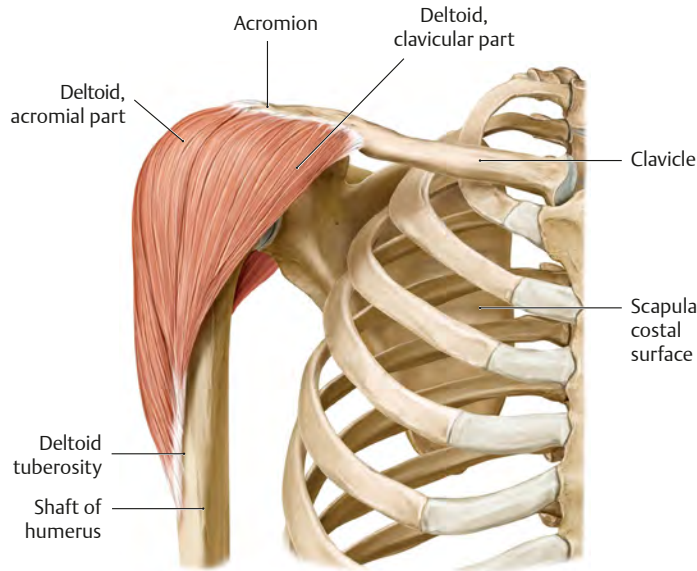
Fig. 25.23 Deltoid
Right shoulder.



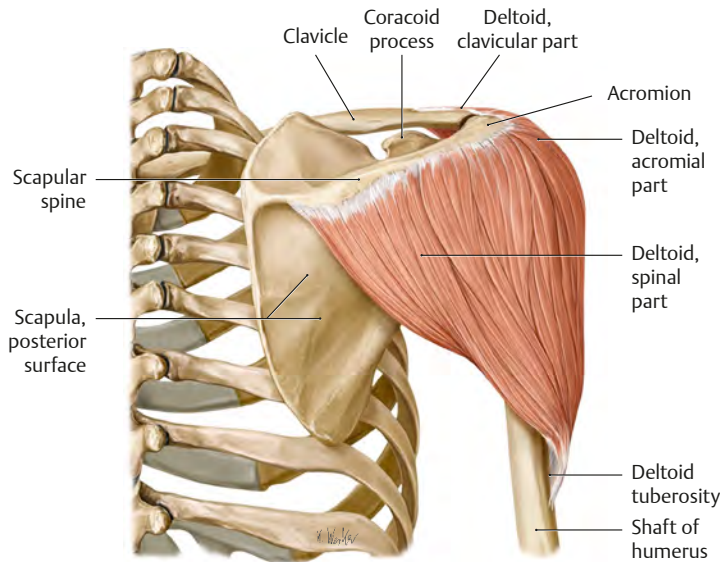
A Parts of the deltoid, right lateral view, schematic.



B Right lateral view.



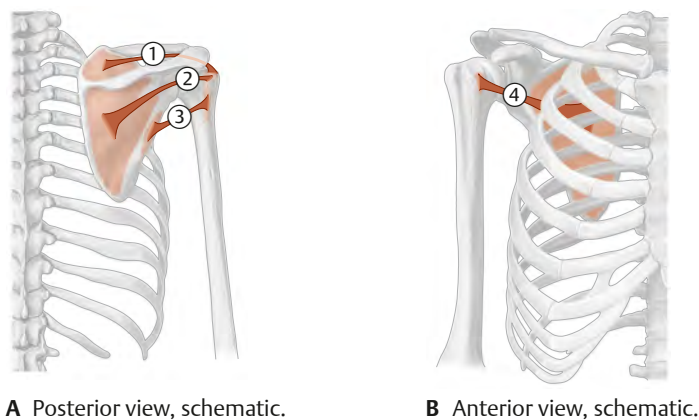
C Anterior view.



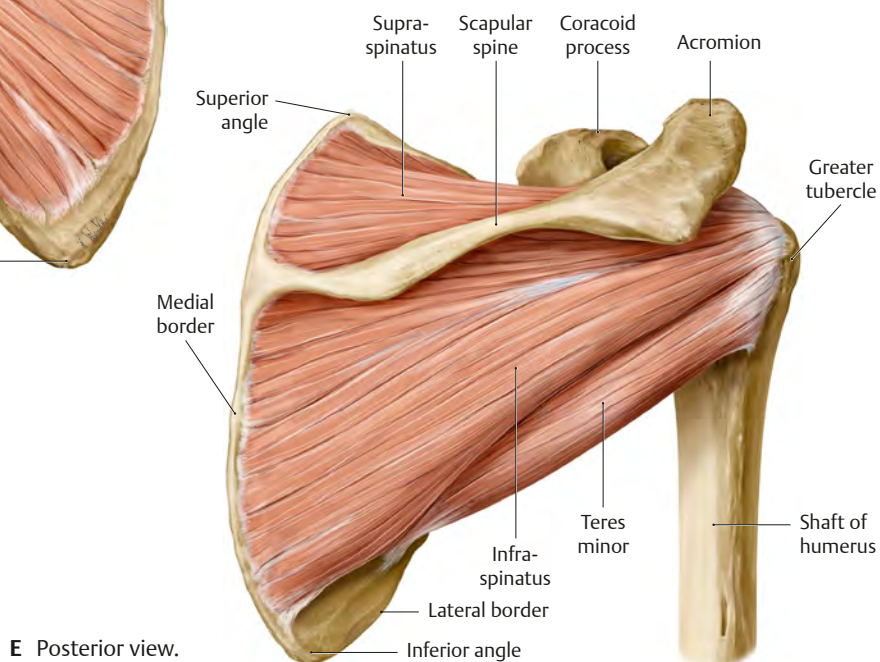
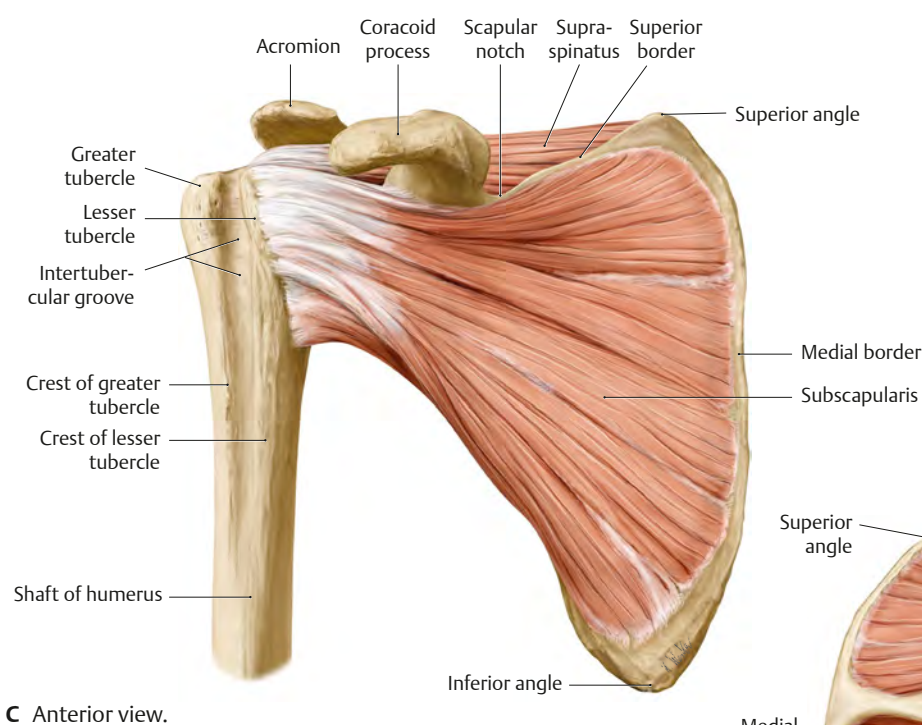
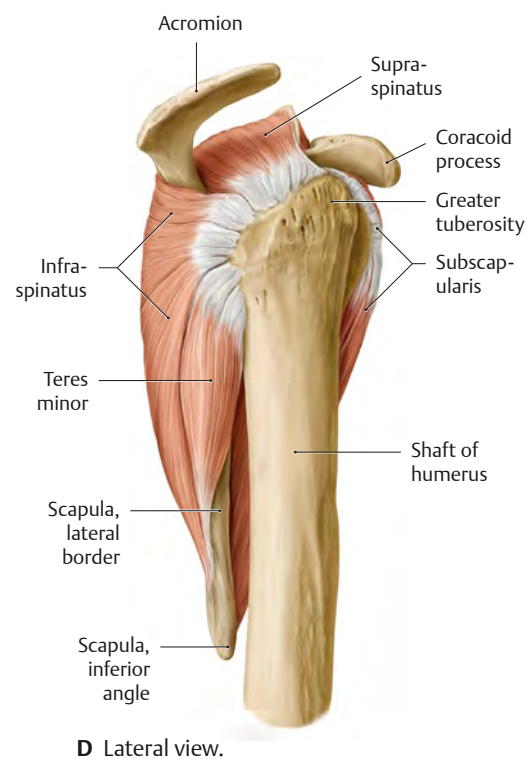
D Posterior view.

Table 25.1 Parts of the deltoid

Muscle		Origin	Insertion	Innervation	Action*
Deltoid	① Clavicular (anterior) part	Lateral one third of clavicle	Humerus (deltoid tuberosity)	Axillary n. (C5, C6)	Flexion, internal rotation, adduction
	② Acromial (lateral) part	Acromion			Abduction
	③ Spinal (posterior) part	Scapular spine			Extension, external rotation, adduction
* Between 60 and 90 degrees of abduction, the clavicular and spinal parts assist the acromial part with abduction.					

**Fig. 25.24 Rotator cuff**

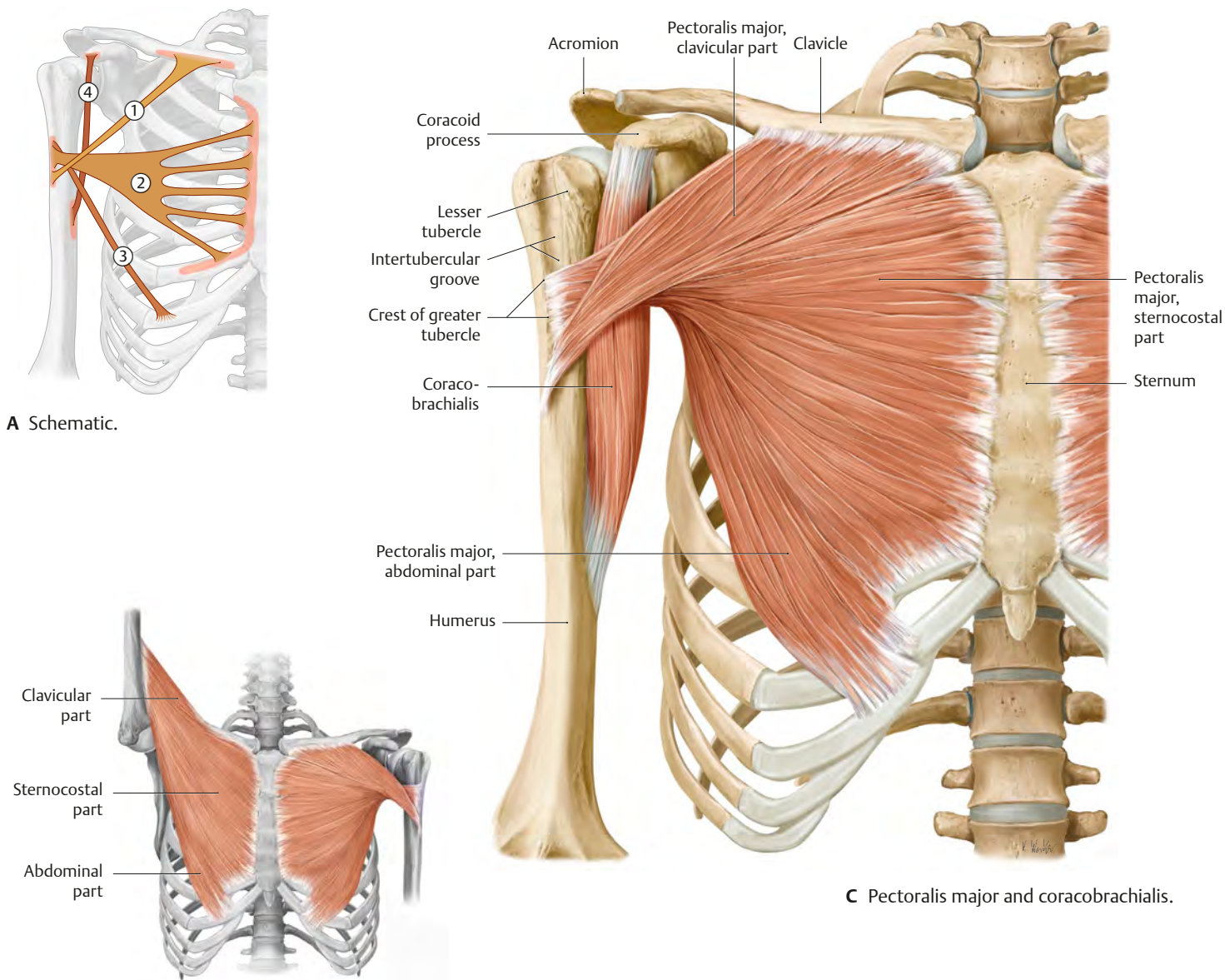
Right shoulder. The rotator cuff consists of four muscles: supraspinatus, infraspinatus, teres minor, and subscapularis.

**Table 25.2****Muscles of the rotator cuff**

Muscle	Origin	Insertion	Innervation	Action
① Supraspinatus	Scapula	Supraspinous fossa	Suprascapular n. (C4–C6)	Initiates abduction
② Infraspinatus		Infraspinous fossa		External rotation
③ Teres minor		Lateral border	Axillary n. (C5, C6)	External rotation, weak adduction
④ Subscapularis		Subscapular fossa	Upper and lower subscapular nn. (C5, C6)	Internal rotation

Muscle Facts (II)

Fig. 25.25 Pectoralis major and coracobrachialis
Anterior view.



B Pectoralis major in neutral position (left) and elevation (right).

C Pectoralis major and coracobrachialis.

Table 25.3 Pectoralis major and coracobrachialis					
Muscle		Origin	Insertion	Innervation	Action
Pectoralis major	① Clavicular part	Clavicle (medial half)	Humerus (crest of greater tubercle)	Medial and lateral pectoral nn. (C5–T1)	Entire muscle: adduction, internal rotation Clavicular and sternocostal parts: flexion; assist in respiration when shoulder is fixed
	② Sternocostal part	Sternum and costal cartilages 1–6			
	③ Abdominal part	Rectus sheath (anterior layer)			
④ Coracobrachialis		Scapula (coracoid process)	Humerus (in line with crest of lesser tubercle)	Musculocutaneous n. (C5–C7)	Flexion, adduction, internal rotation

Fig. 25.26 Subclavius and pectoralis minor
Right side, anterior view.

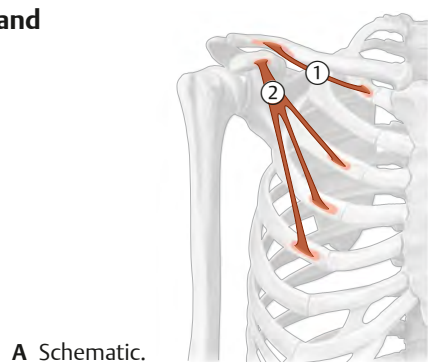
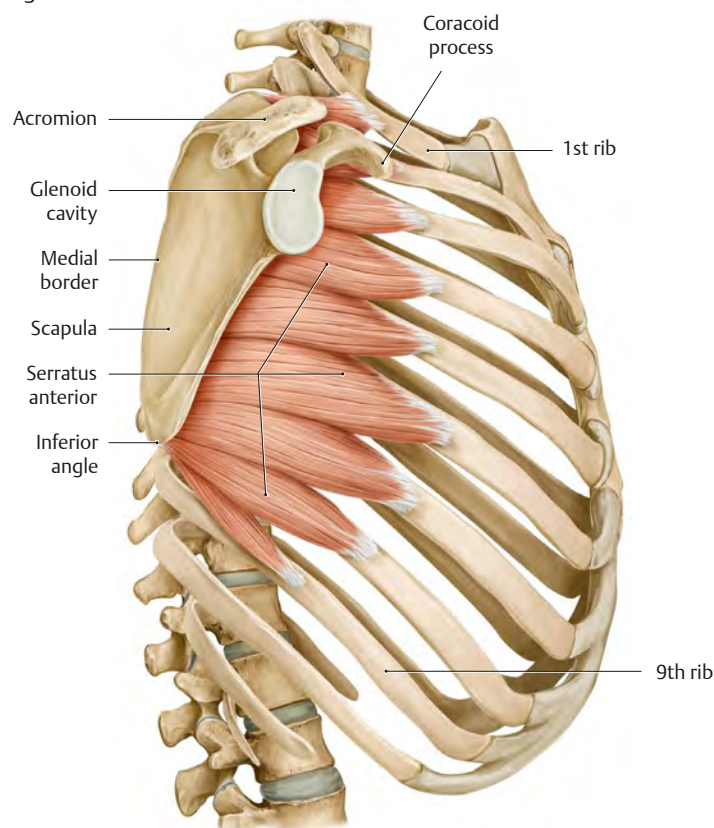


Fig. 25.27 Serratus anterior
Right lateral view.



A Serratus anterior.

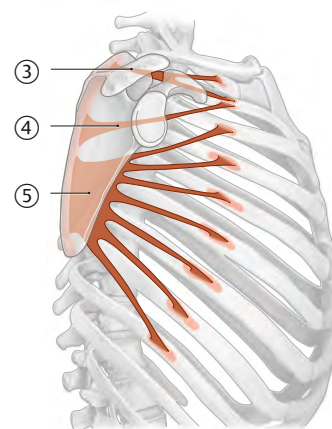
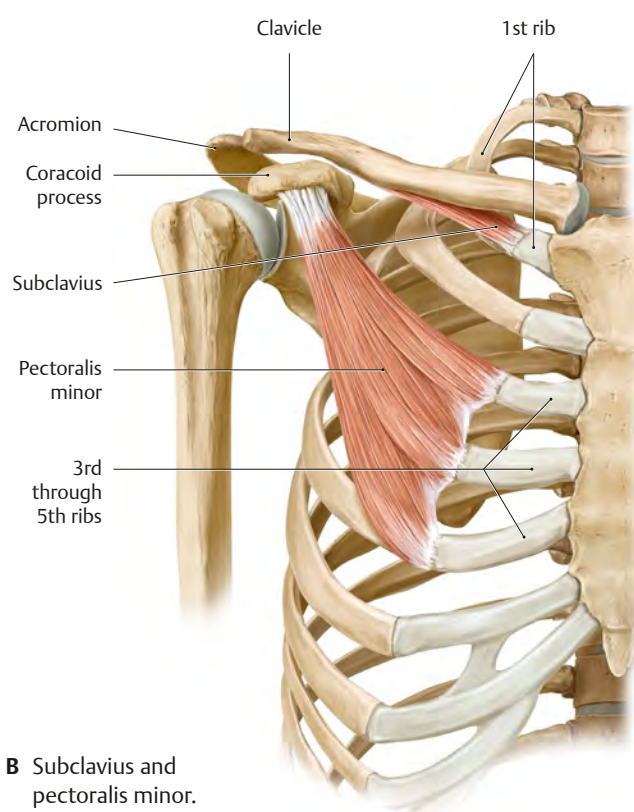


Table 25.4

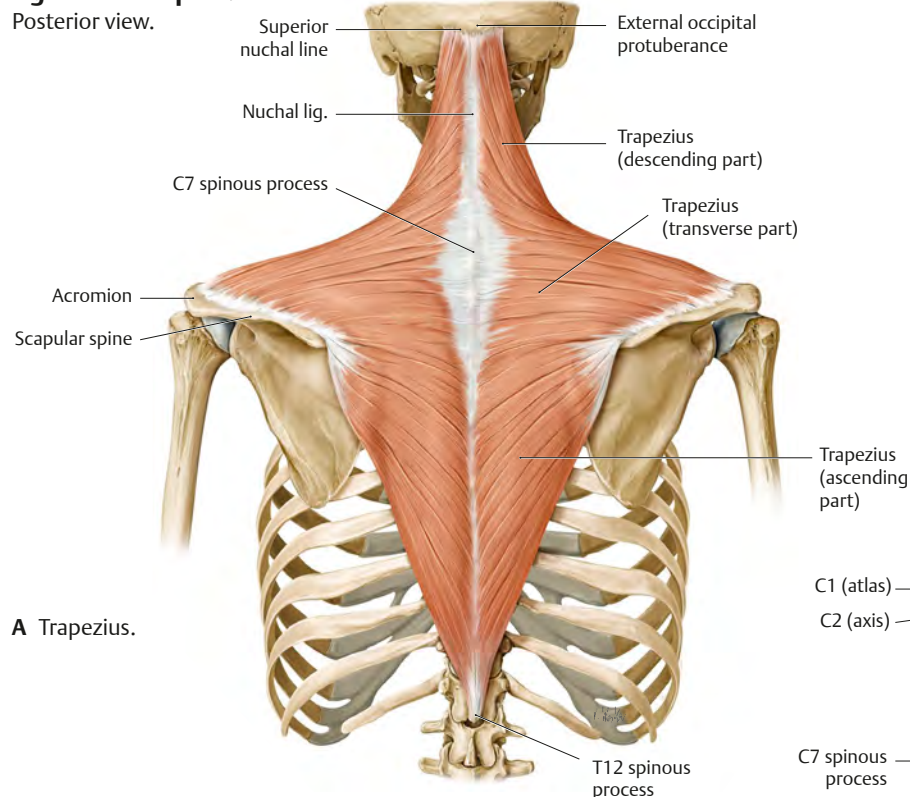
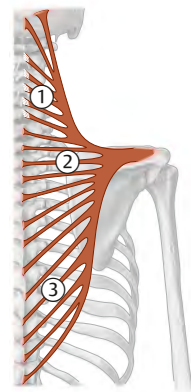
Subclavius, pectoralis minor, and serratus anterior

Muscle	Origin	Insertion	Innervation	Action
① Subclavius	1st rib	Clavicle (inferior surface)	N. to subclavius (C5, C6)	Steadies the clavicle in the sternoclavicular joint
② Pectoralis minor	3rd to 5th ribs	Coracoid process	Medial pectoral n. (C8, T1)	Draws scapula downward, causing inferior angle to move posteromedially; rotates glenoid inferiorly; assists in respiration
Serratus anterior	③ Superior part	Scapula (costal and dorsal surfaces of superior angle)	Long thoracic n. (C5–C7)	Superior part: lowers the raised arm
	④ Intermediate part	Scapula (costal surface of medial border)		Entire muscle: draws scapula laterally forward; elevates ribs when shoulder is fixed
	⑤ Inferior part	Scapula (costal surface of medial border and costal and dorsal surfaces of inferior angle)		Inferior part: rotates inferior angle of scapula laterally forward (allows elevation of arm above 90°)

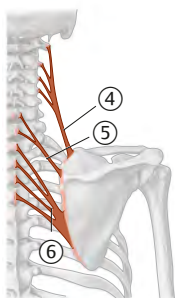
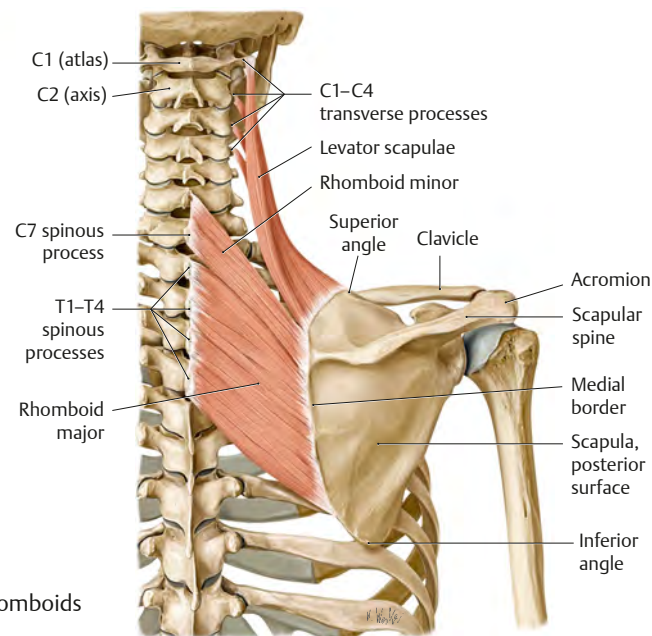
Muscle Facts (III)

Fig. 25.28 Trapezius

Posterior view.

**A Trapezius.****B Schematic.****Fig. 25.29 Levator scapulae with rhomboids major and minor**

Right side, posterior view.

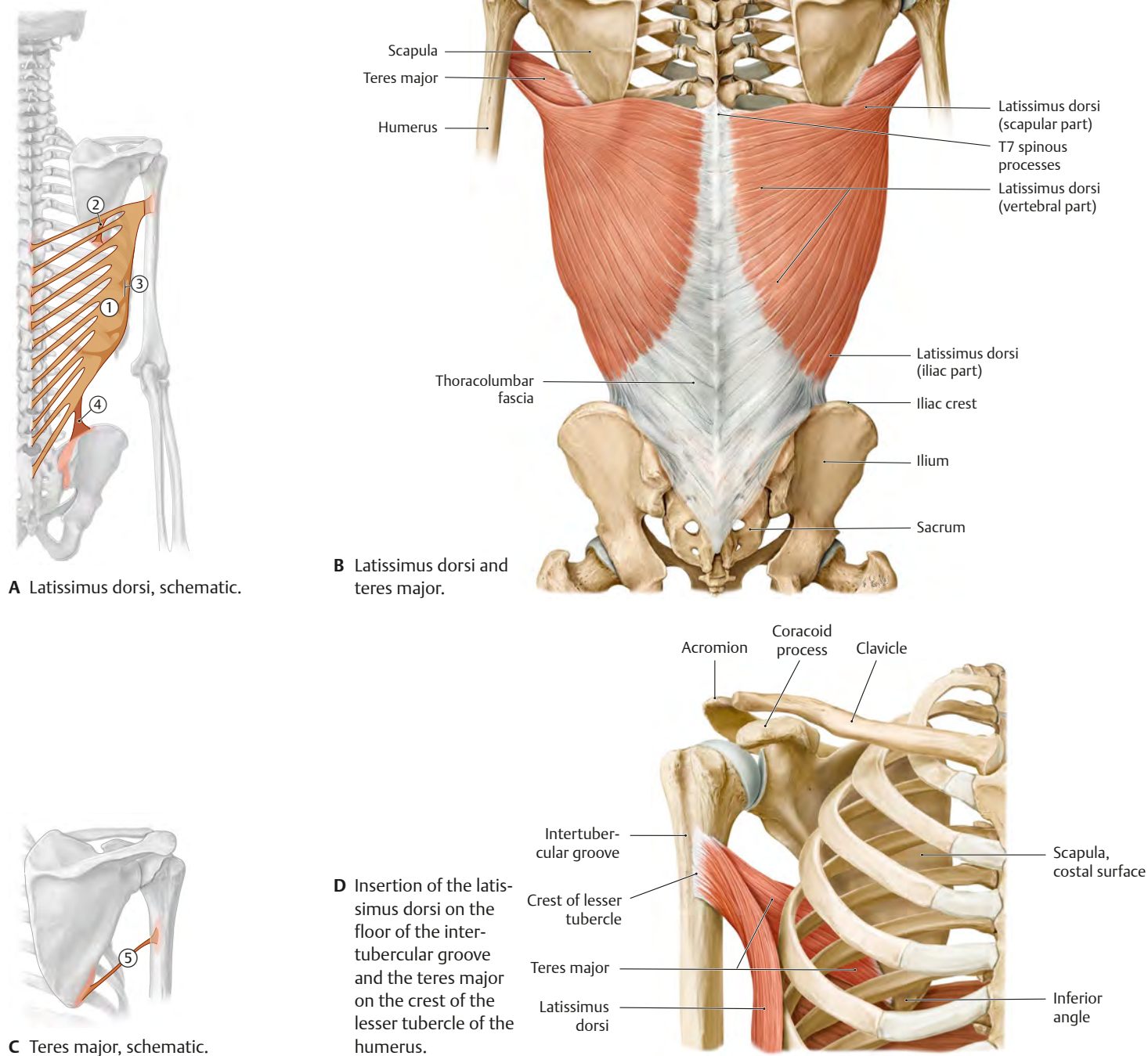
**A Schematic.****B Levator scapulae with rhomboids major and minor.****Table 25.5****Trapezius, levator scapulae, and rhomboids major and minor**

Muscle		Origin	Insertion	Innervation	Action
Trapezius	① Descending part	Occipital bone; spinous processes of C1–C7	Clavicle (lateral one third)	Accessory n. (CN XI); C3–C4 of cervical plexus	Draws scapula obliquely upward; rotates glenoid cavity superiorly; tilts head to same side and rotates it to opposite
	② Transverse part	Aponeurosis at T1–T4 spinous processes	Acromion		Draws scapula medially
	③ Ascending part	Spinous processes of T5–T12	Scapular spine		Draws scapula medially downward Entire muscle: steadies scapula on thorax
④ Levator scapulae		Transverse processes of C1–C4	Scapula (superior angle)	Dorsal scapular n. and cervical spinal nn. (C3–C4)	Draws scapula medially upward while moving inferior angle medially; inclines neck to same side
⑤ Rhomboid minor		Spinous processes of C6, C7	Medial border of scapula above (minor) and below (major) scapular spine	Dorsal scapular n. (C4–C5)	Steadies scapula; draws scapula medially upward
⑥ Rhomboid major		Spinous processes of T1–T4 vertebrae			

CN, cranial nerve.

Fig. 25.30 Latissimus dorsi and teres major

Posterior view.

**Table 25.6****Latissimus dorsi and teres major**

Muscle		Origin	Insertion	Innervation	Action
Latissimus dorsi	① Vertebral part	Spinous processes of T7–T12 vertebrae; thoracolumbar fascia	Floor of the intertubercular groove of the humerus	Thoracodorsal n. (C6–C8)	Internal rotation, adduction, extension, respiration (“cough muscle”)
	② Scapular part	Scapula (inferior angle)			
	③ Costal part	9th to 12th ribs			
	④ Iliac part	Iliac crest (posterior one third)			
⑤ Teres major		Scapula (inferior angle)	Crest of lesser tubercle of the humerus (anterior angle)	Lower subscapular n. (C5, C6)	Internal rotation, adduction, extension

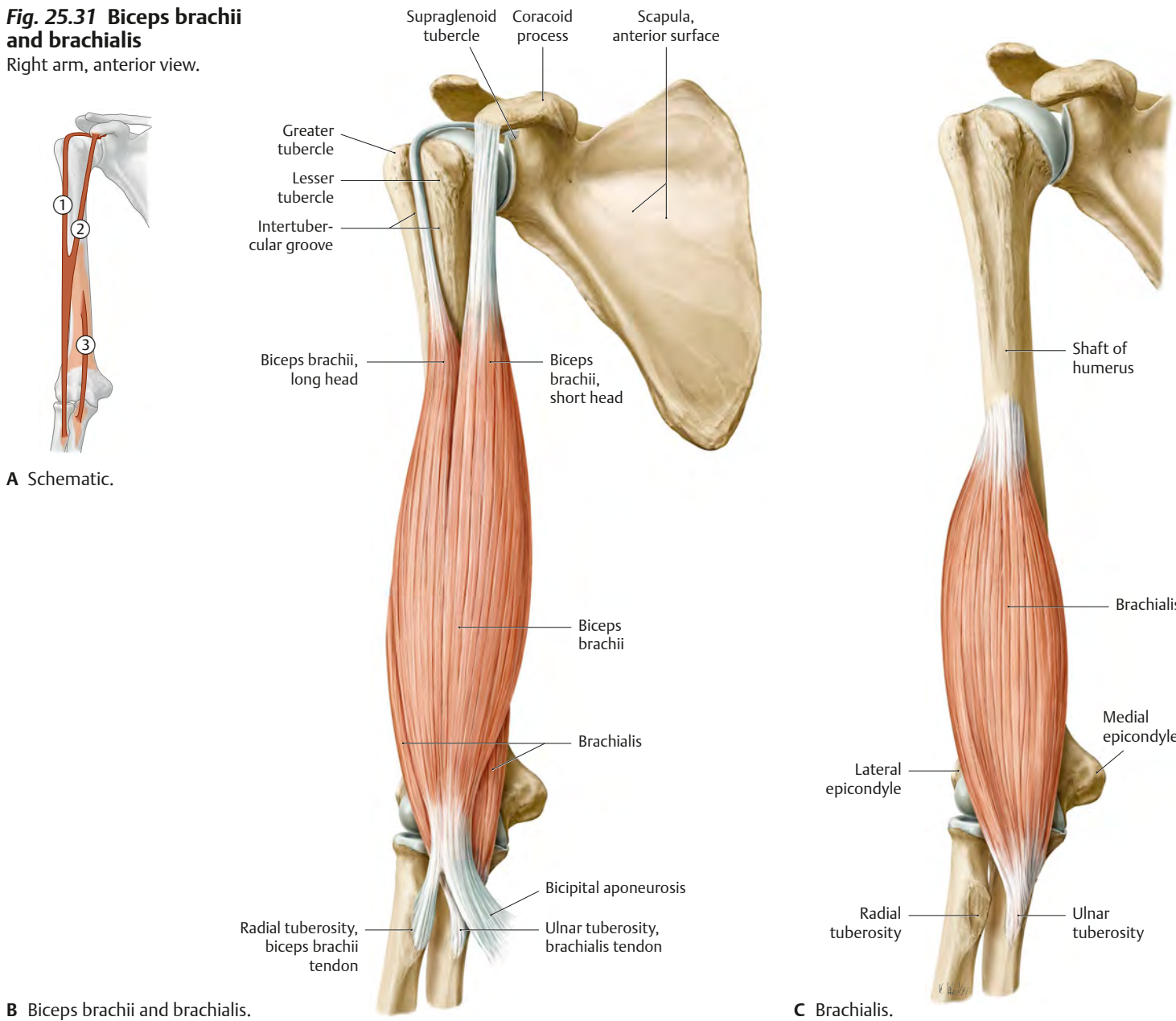
Muscle Facts (IV)

The anterior and posterior muscles of the arm may be classified respectively as flexors and extensors relative to the movement of the elbow joint. Although the coracobrachialis is topographically part of the

anterior compartment, it is functionally grouped with the muscles of the shoulder (see p. 318).

Fig. 25.31 Biceps brachii and brachialis

Right arm, anterior view.



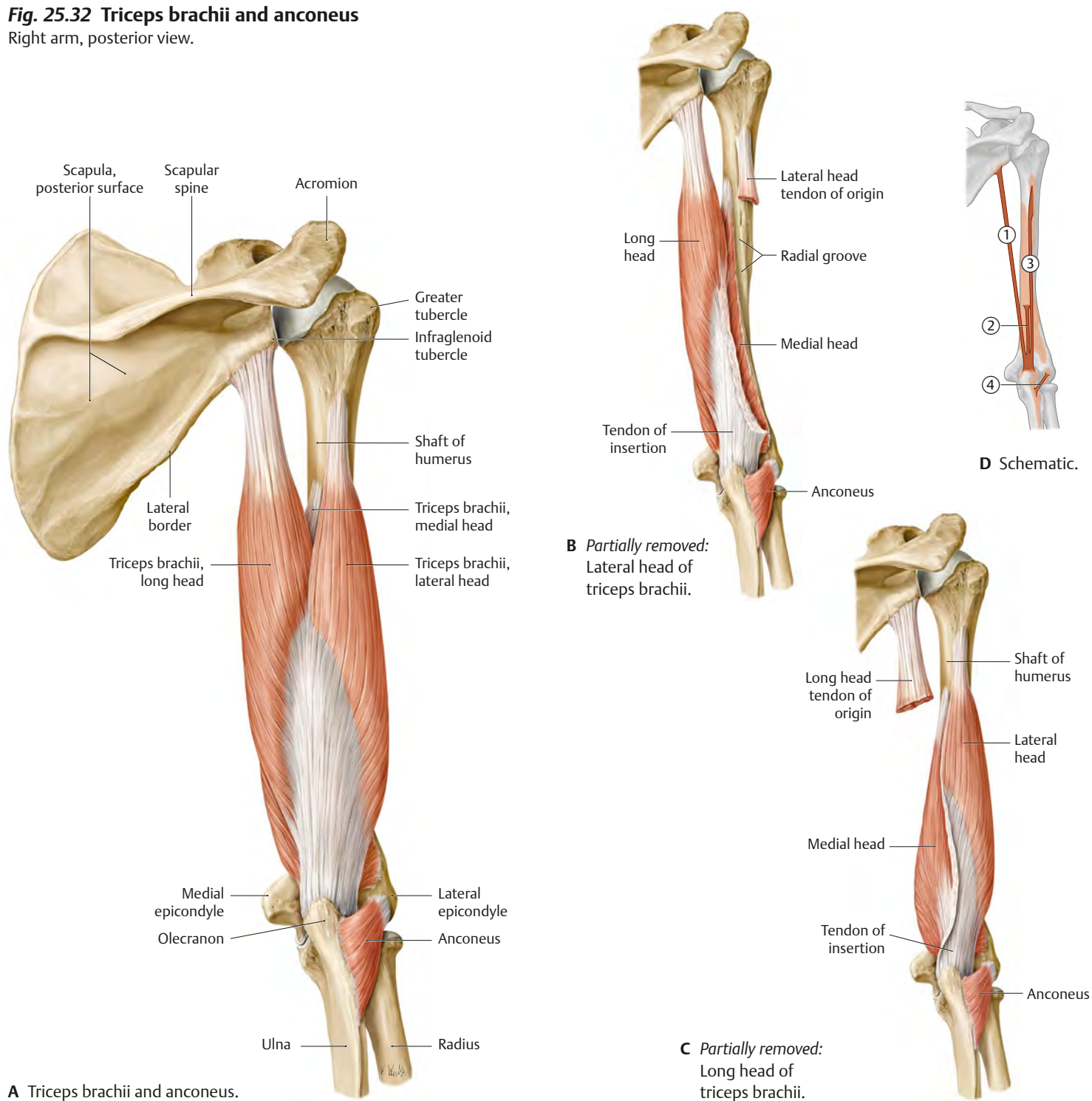
B Biceps brachii and brachialis.

C Brachialis.

Table 25.7 Anterior muscles: Biceps brachii and brachialis					
Muscle		Origin	Insertion	Innervation	Action
Biceps brachii	① Long head	Supraglenoid tubercle of scapula	Radial tuberosity and bicipital aponeurosis	Musculocutaneous n. (C5–C6)	Elbow joint: flexion; supination* Shoulder joint: flexion; stabilization of humeral head during deltoid contraction; abduction and internal rotation of the humerus
	② Short head	Coracoid process of scapula			
③ Brachialis		Humerus (distal half of anterior surface)	Ulnar tuberosity	Musculocutaneous n. (C5–C6) and radial n. (C7, minor)	Flexion at the elbow joint
* Note: When the elbow is flexed, the biceps brachii acts as a powerful supinator because the lever arm is almost perpendicular to the axis of pronation/supination.					

Fig. 25.32 Triceps brachii and anconeus

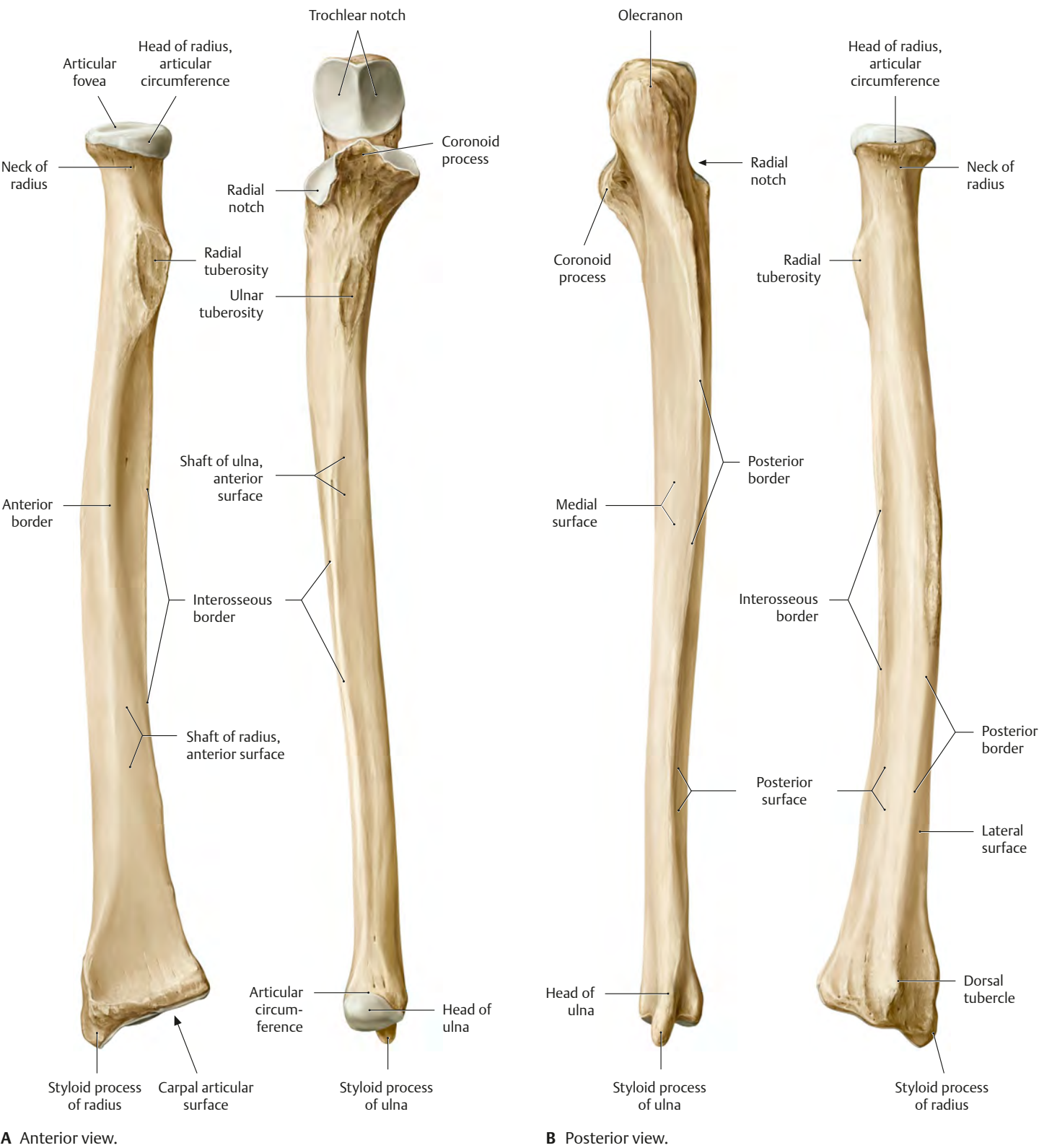
Right arm, posterior view.

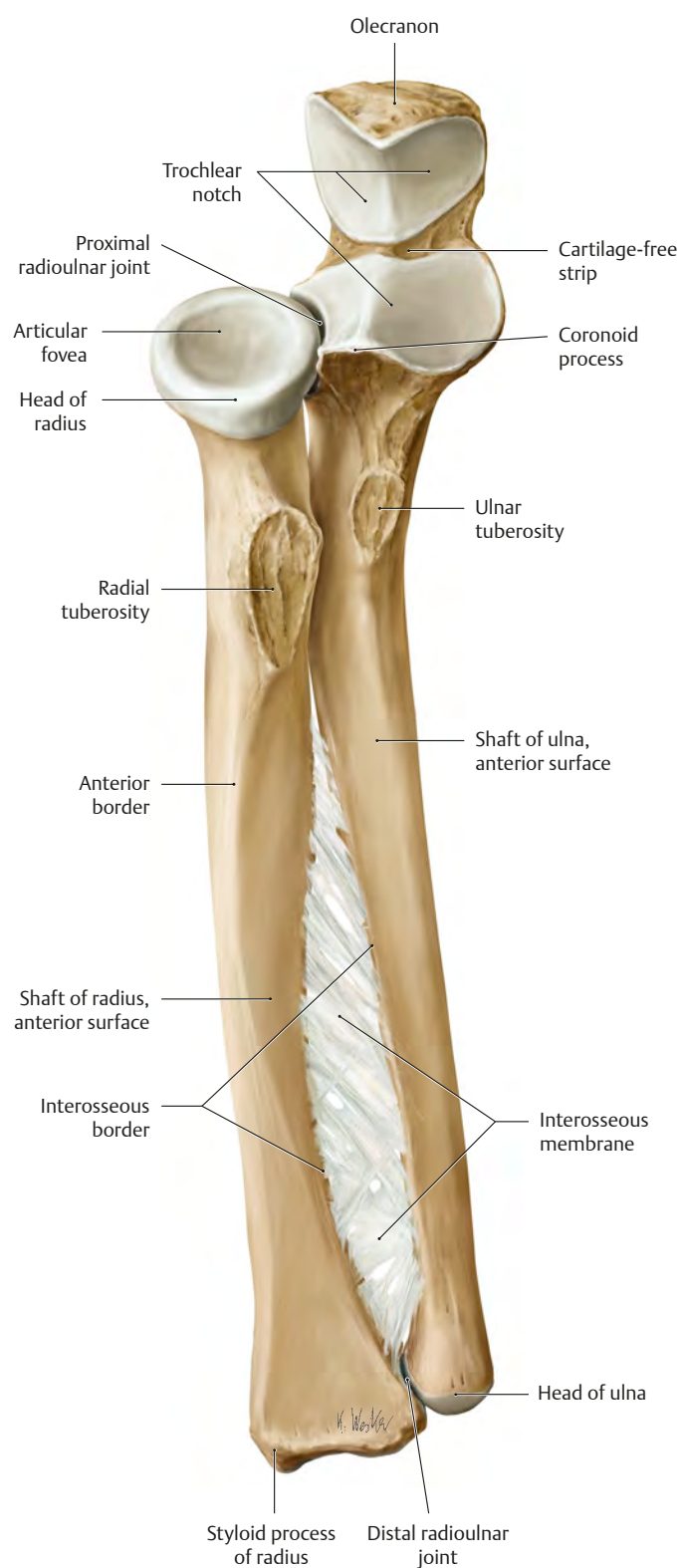
**Table 25.8** Posterior muscles: Triceps brachii and anconeus

Muscle	Origin	Insertion	Innervation	Action
Triceps brachii	① Long head	Scapula (infraglenoid tubercle)	Radial n. (C6–C8)	Elbow joint: extension Shoulder joint, long head: extension and adduction
	② Medial head	Posterior humerus, distal to radial groove; medial intermuscular septum		
	③ Lateral head	Posterior humerus, proximal to radial groove; lateral intermuscular septum		
④ Anconeus	Lateral epicondyle of humerus (variance: posterior joint capsule)	Olecranon of ulna (radial surface)		Extends the elbow and tightens its joint

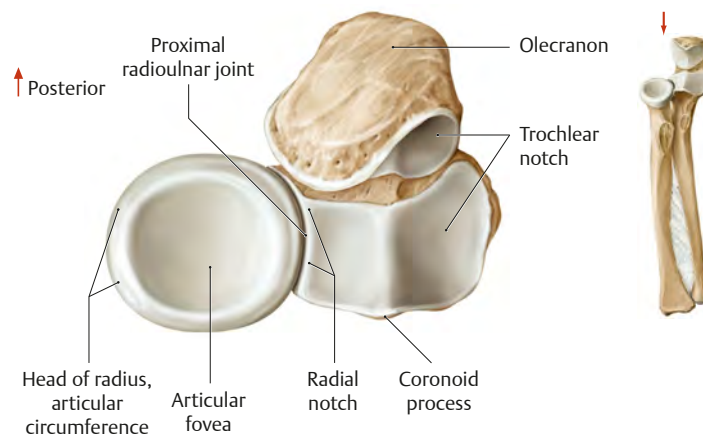
26 Elbow & Forearm Radius & Ulna

Fig. 26.1 Radius and ulna
Right forearm.

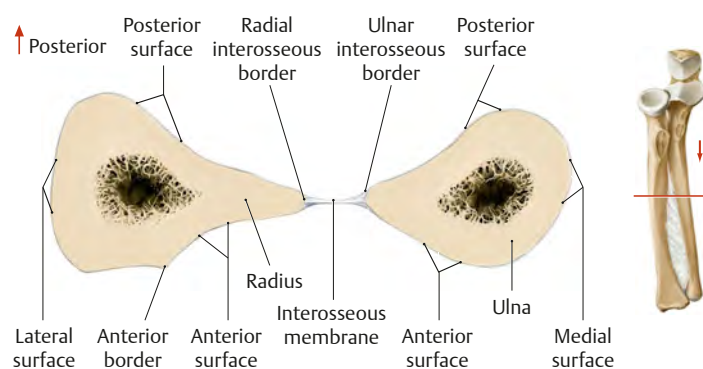




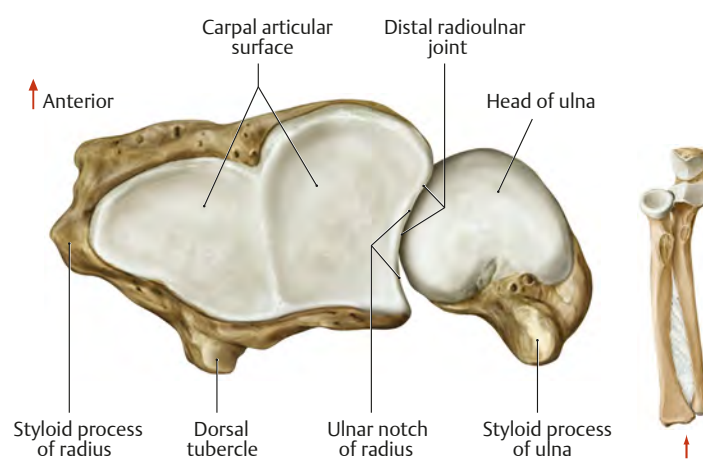
C Anterosuperior view.



D Proximal (superior) view.



E Transverse section, proximal view.

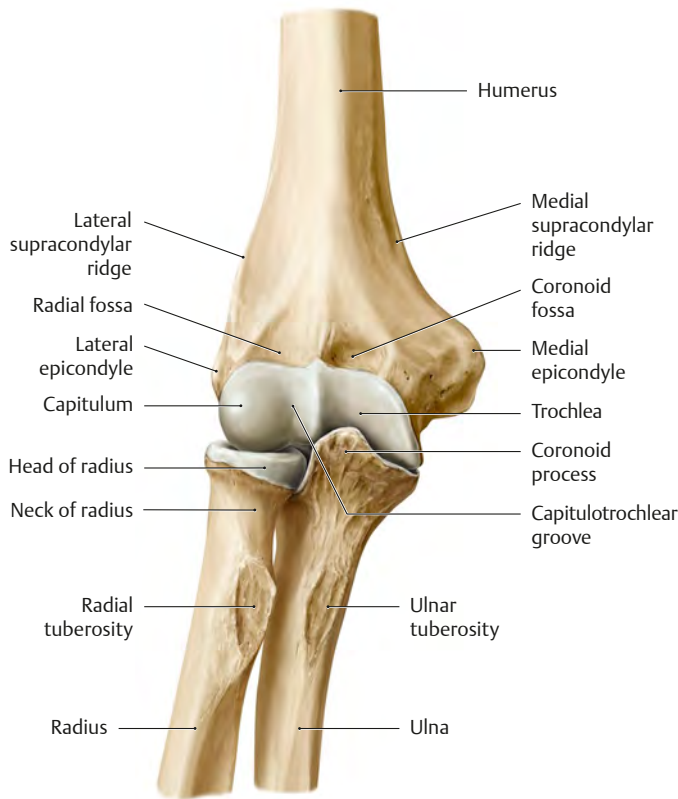


F Distal (inferior) view.

Elbow Joint

Fig. 26.2 Elbow (cubital) joint

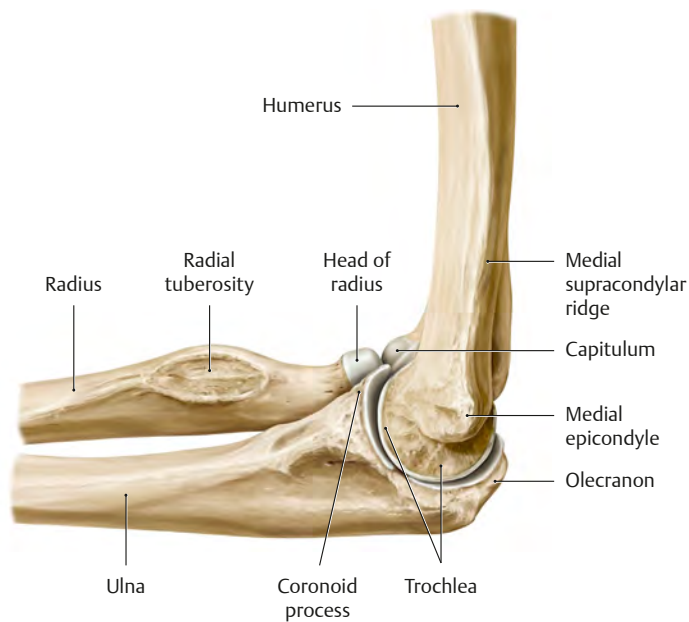
Right limb. The elbow consists of three articulations between the humerus, ulna, and radius: the humeroulnar, humeroradial, and proximal radioulnar joints.



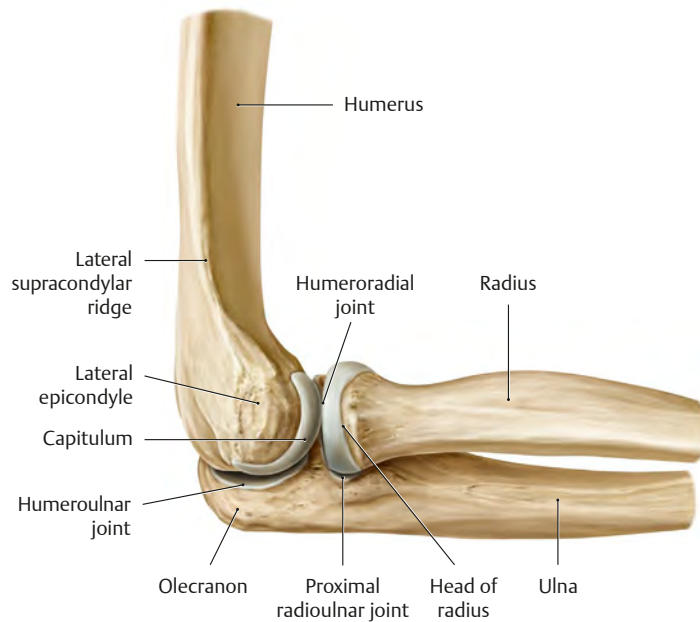
A Anterior view.



B Posterior view.

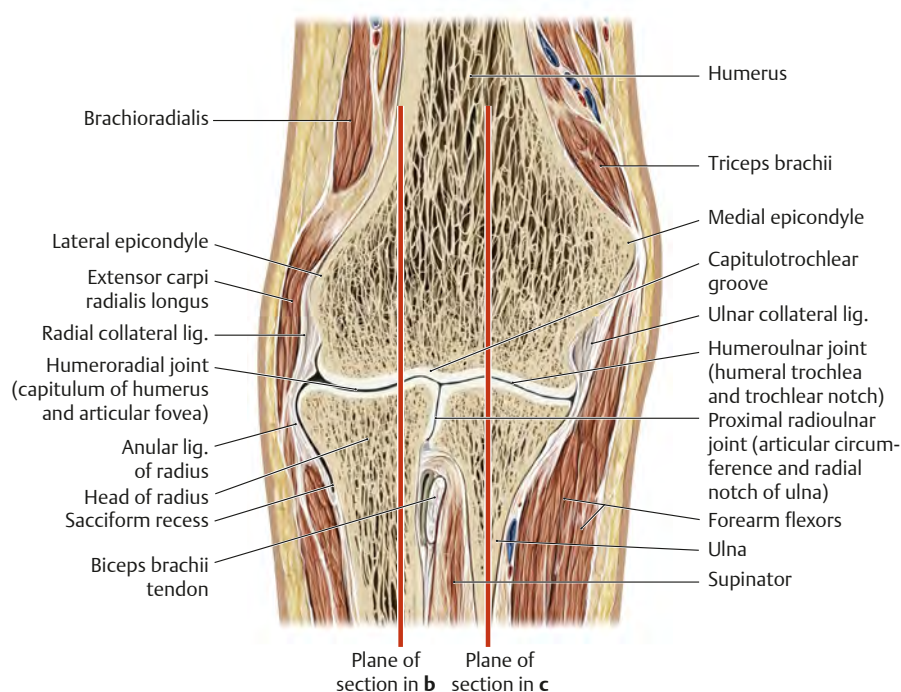


C Medial view.



D Lateral view.

Fig. 26.3 Skeletal and soft-tissue elements of the right elbow joint



A Coronal section viewed from the front (note the planes of section shown in **B** and **C**).

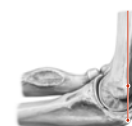
Clinical box 26.1

Assessing elbow injuries

The fat pads between the fibrous capsule and synovial membrane are part of the normal anatomy of the elbow joint. The anterior pad is most readily seen on a sagittal MRI while the posterior pad is often hidden within the bony fossa (see **Figs. 26.3** and **29.11**). With an effusion of the joint space, the inferior edge of the anterior pad appears concave as it gets pushed superiorly by the intra-articular fluid. This causes the pad to resemble the shape of a ship's sail, thus creating a characteristic "sail sign." The alignment of the prominences in the elbow also aids in the identification of fractures and dislocations.



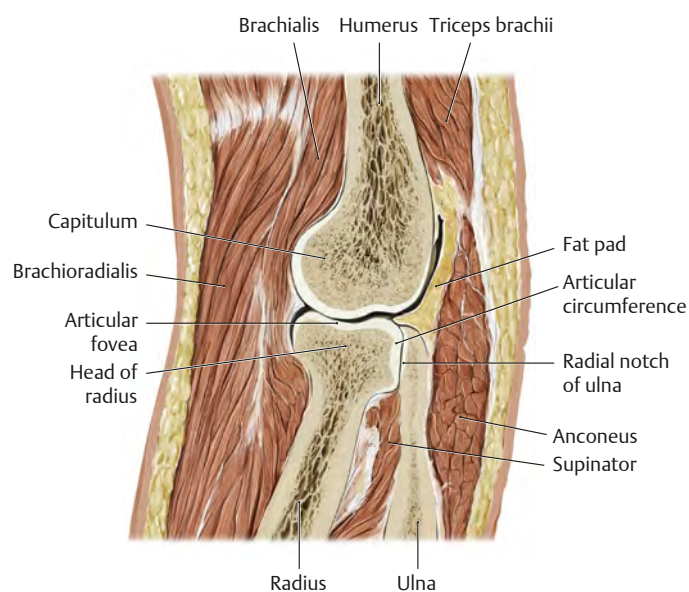
A Posterior view of extended elbow: The epicondyles and olecranon lie in a straight line.



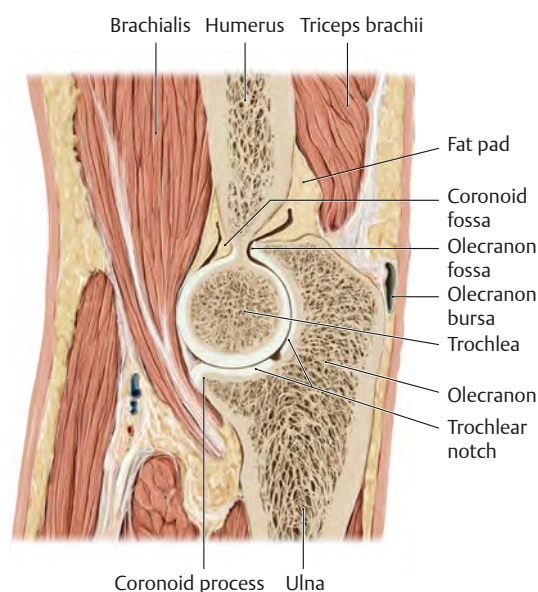
B Medial view of flexed elbow: The epicondyles and olecranon lie in a straight line.



C Posterior view of flexed elbow: The two epicondyles and the tip of the olecranon form an equilateral triangle. Fractures and dislocations alter the shape of the triangle.

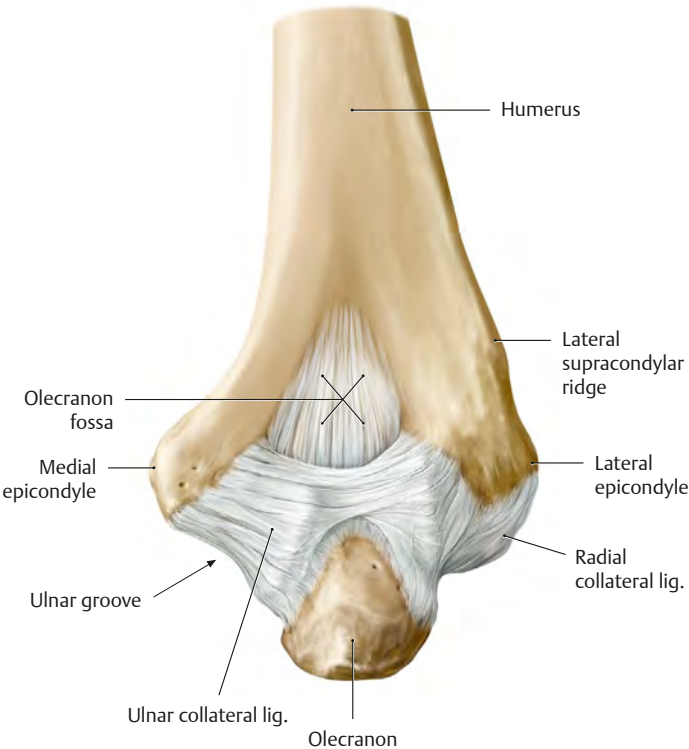


B Sagittal section through the humeroradial joint and proximal radioulnar joint, medial view.



C Sagittal section through the humeroulnar joint, medial view.

Ligaments of the Elbow Joint

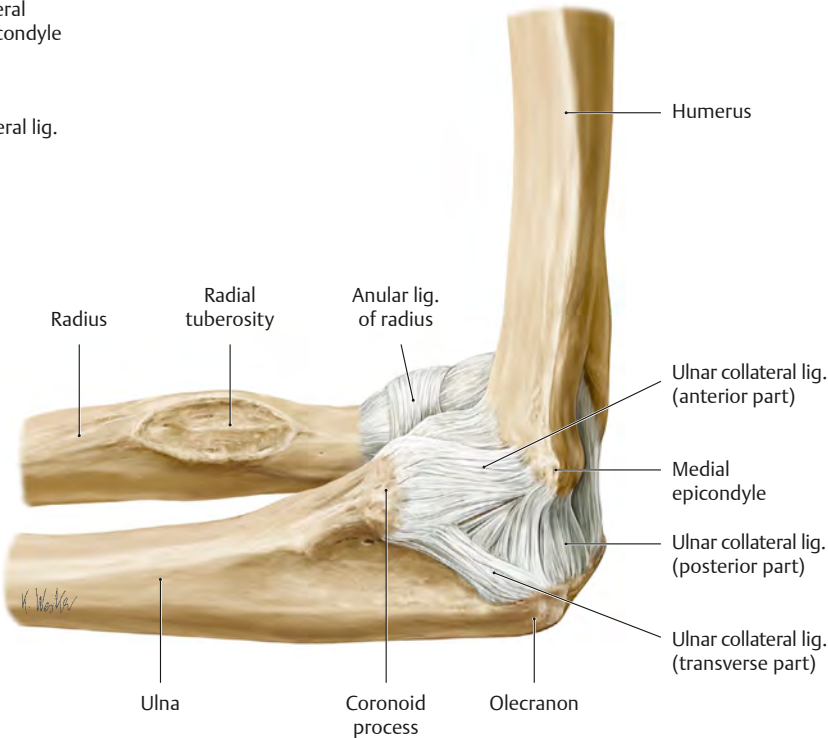


A Posterior view.



C Lateral view.

Fig. 26.4 Ligaments of the elbow joint
Right elbow in flexion.

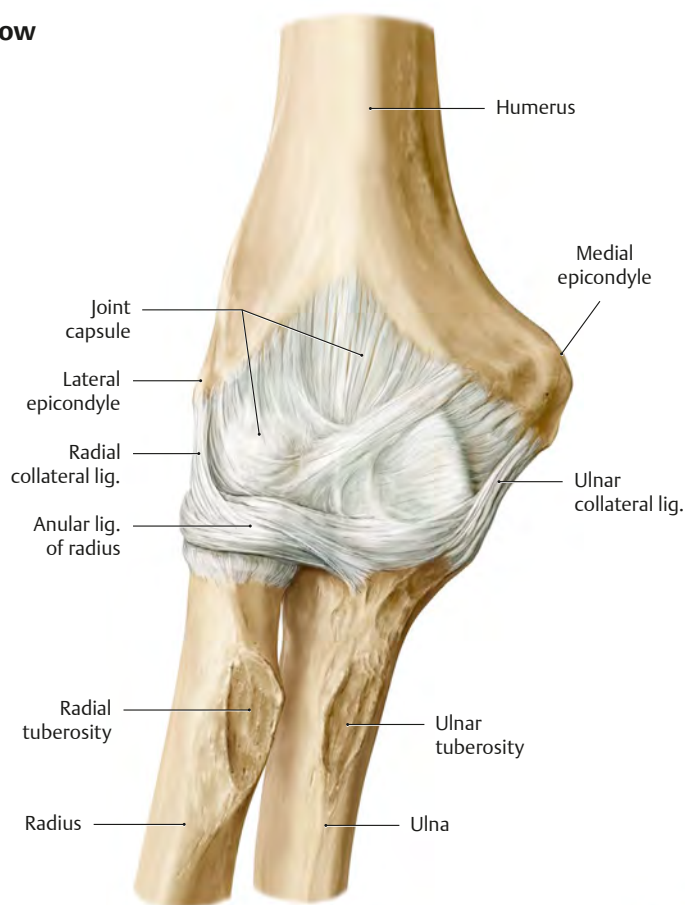


B Medial view.

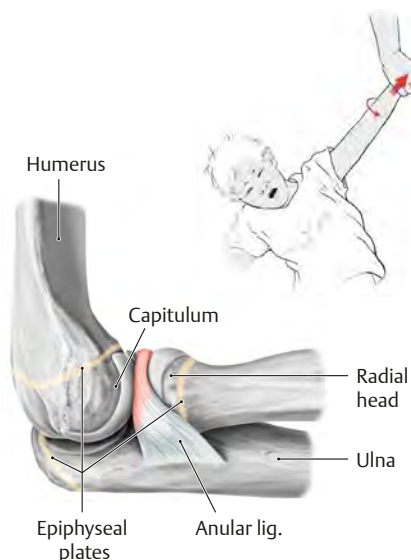
Table 26.1 Joints and ligaments of the elbow			
Joint	Articulating surfaces		Ligament
Humeroulnar joint	Trochlea	Ulna (trochlear notch)	Ulnar collateral ligament
Humeroradial joint	Capitulum	Radius (articular fovea)	Radial collateral ligament
Proximal radioulnar joint	Radius (articular circumference)	Ulna (radial notch)	Annular ligament

Fig. 26.5 Joint capsule of the elbow

Right elbow in extension, anterior view.

**A** Intact joint capsule.**Clinical box 26.2****Subluxation of the radial head (nursemaid's elbow)**

A common and painful injury of small children occurs when the arm is jerked upward with the forearm pronated, tearing the annular ligament from its loose attachment on the radial neck. As the immature radial head slips out of the socket, the ligament may become trapped between the radial head and the capitulum of the humerus. Supinating the forearm and flexing the elbow usually returns the radial head to the normal position.

**B** Windowed joint capsule.

Radioulnar Joints

The proximal and distal radioulnar joints function together to enable pronation and supination movements of the hand. The joints are functionally linked by the interosseous membrane. The axis for pronation

and supination runs obliquely from the center of the humeral capitulum through the center of the radial articular fovea down to the styloid process of the ulna.

Fig. 26.6 Supination

Right forearm, anterior view.

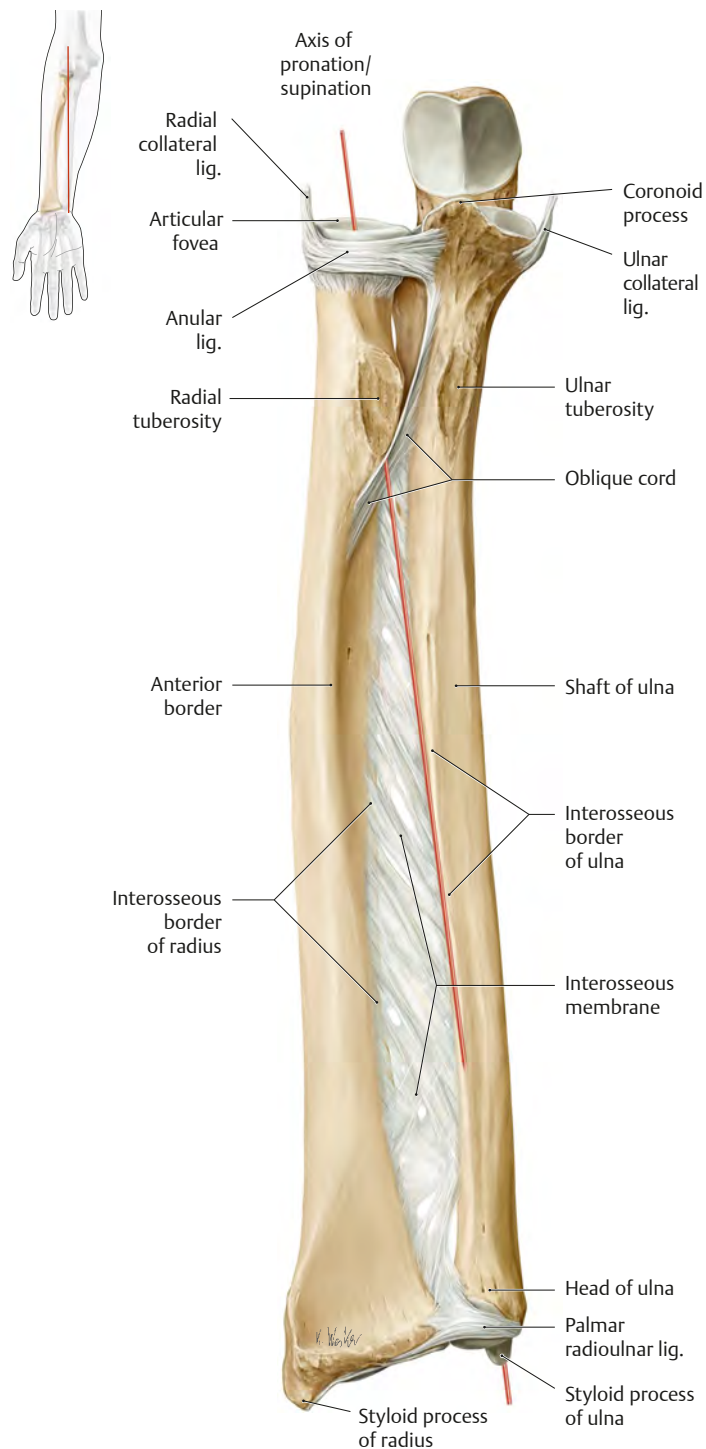


Fig. 26.7 Pronation

Right forearm, anterior view.

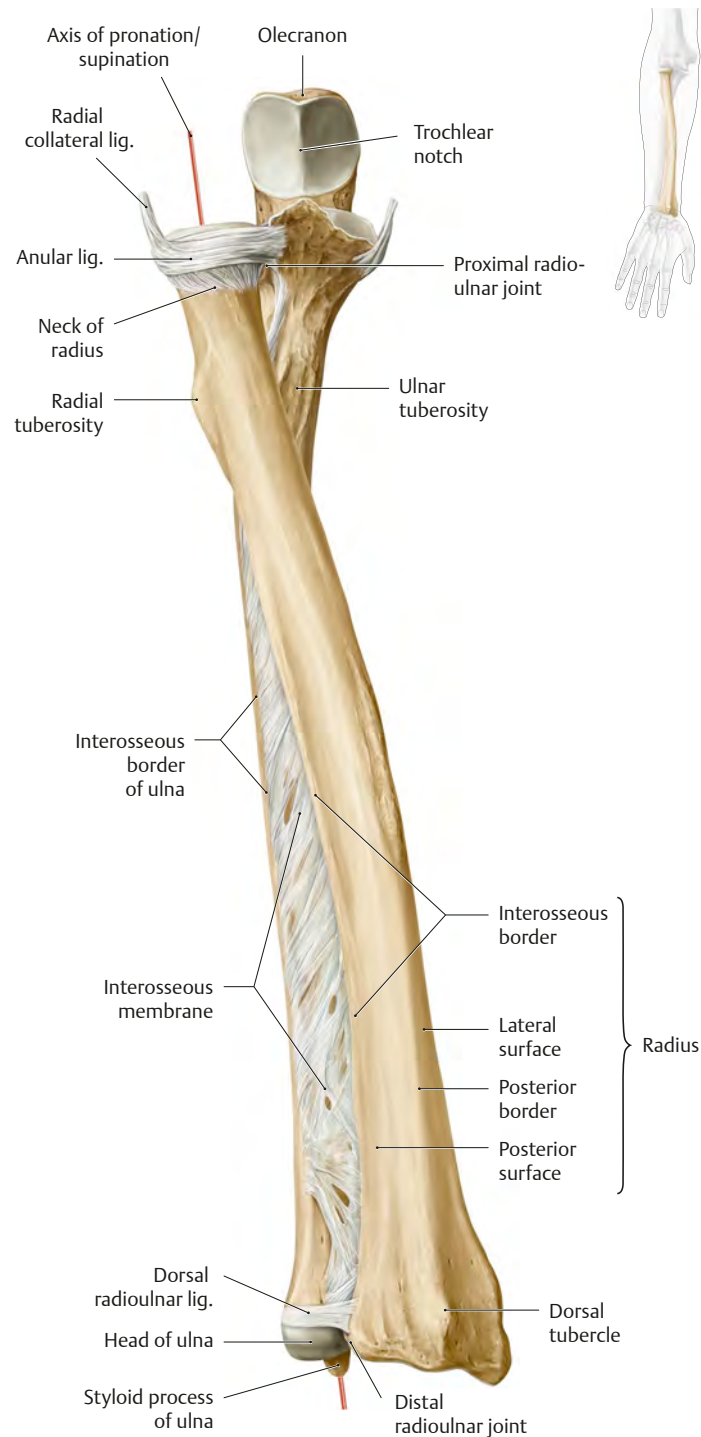
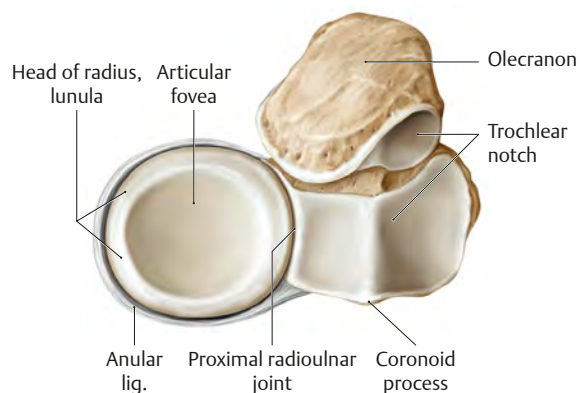
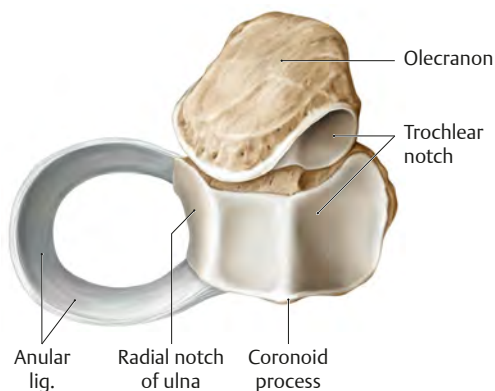
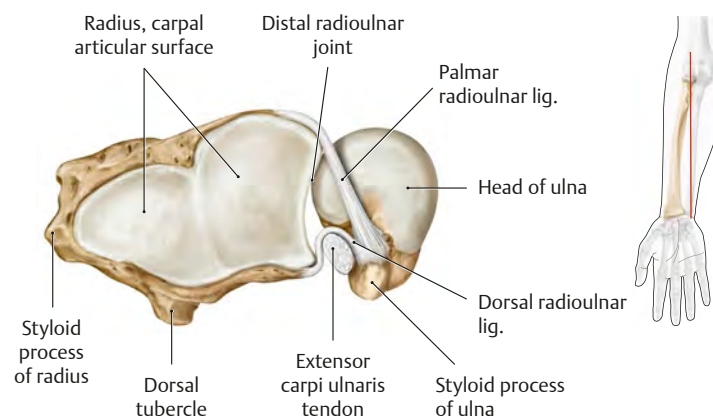
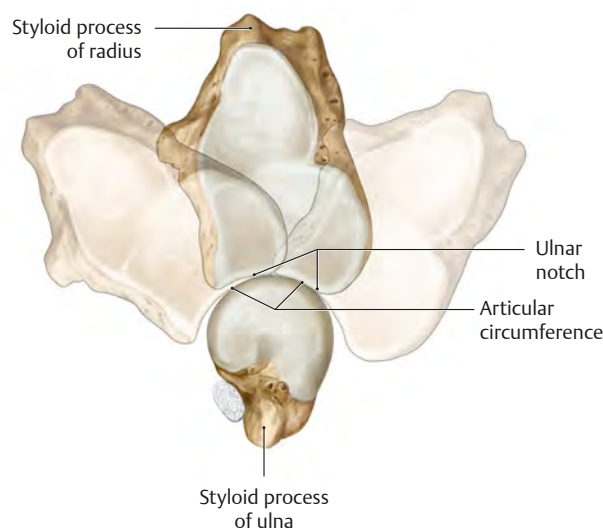
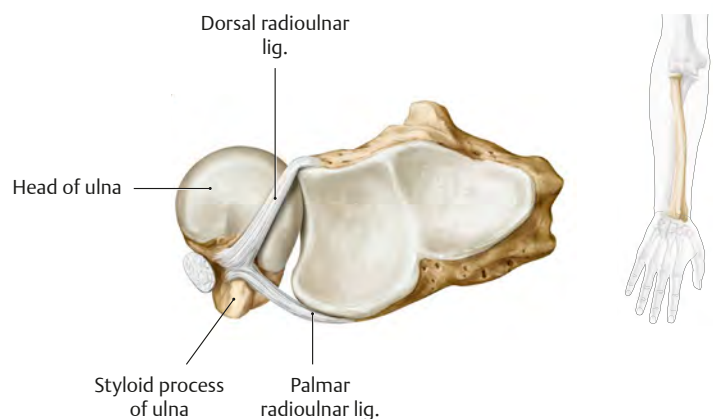


Fig. 26.8 Proximal radioulnar joint

Right elbow, proximal (superior) view.

**A** Proximal articular surfaces of radius and ulna.**B** Radius removed.**Fig. 26.9 Distal radioulnar joint rotation**

Right forearm, distal view of articular surfaces of radius and ulna. The dorsal and palmar radioulnar ligaments stabilize the distal radioulnar joint.

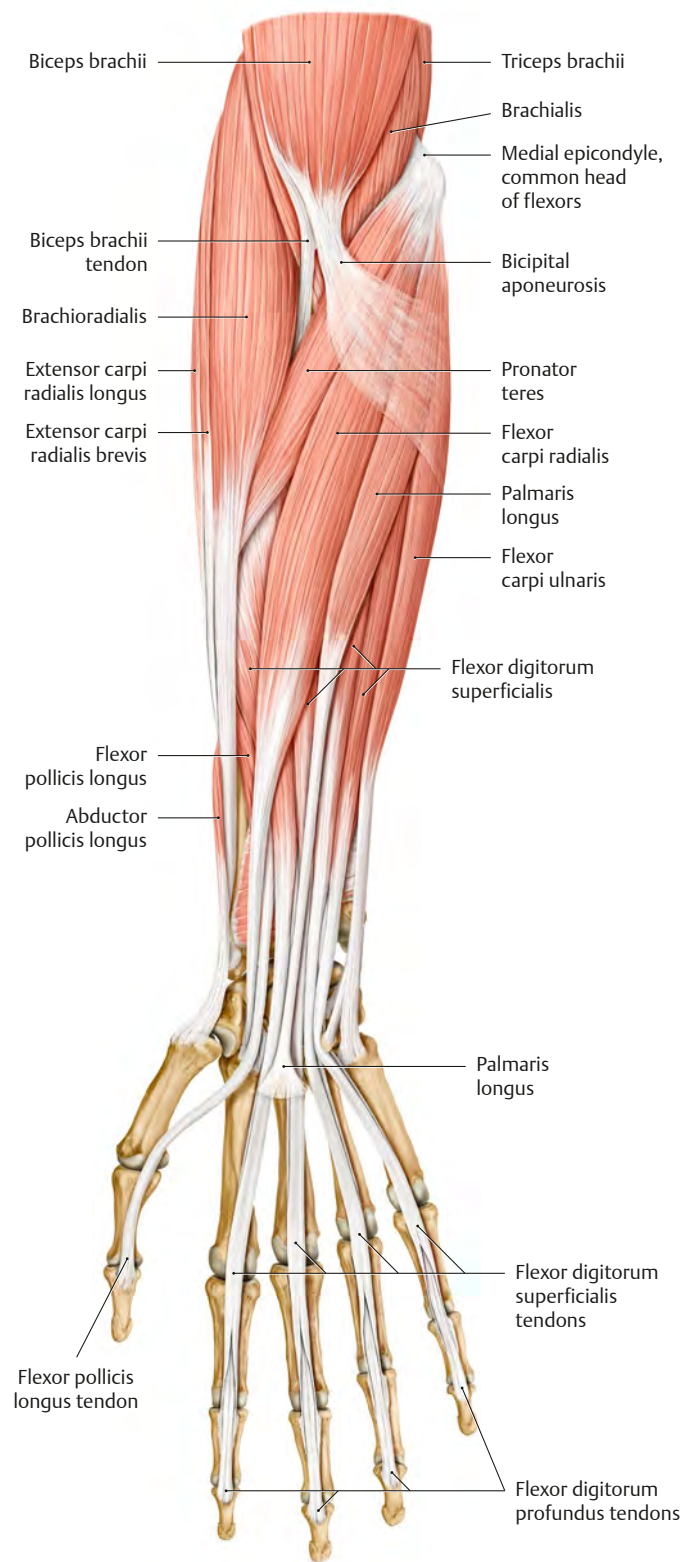
**A** Supination.**B** Semipronation.**C** Pronation.**Clinical box 26.3****Radius fracture**

Falls onto the outstretched arm often result in fractures of the distal radius. In a Colles' fracture, the distal fragment is tilted dorsally.

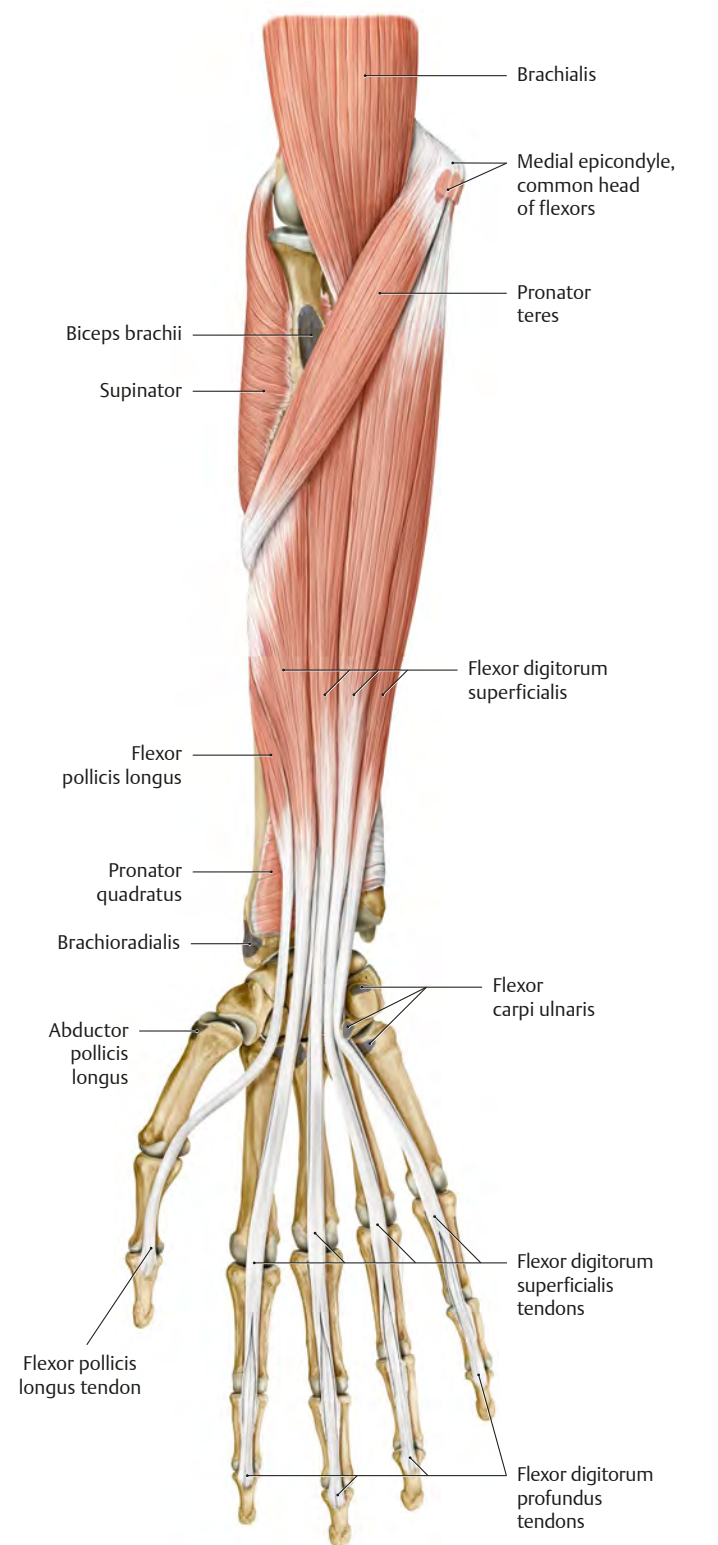


Muscles of the Forearm: Anterior Compartment

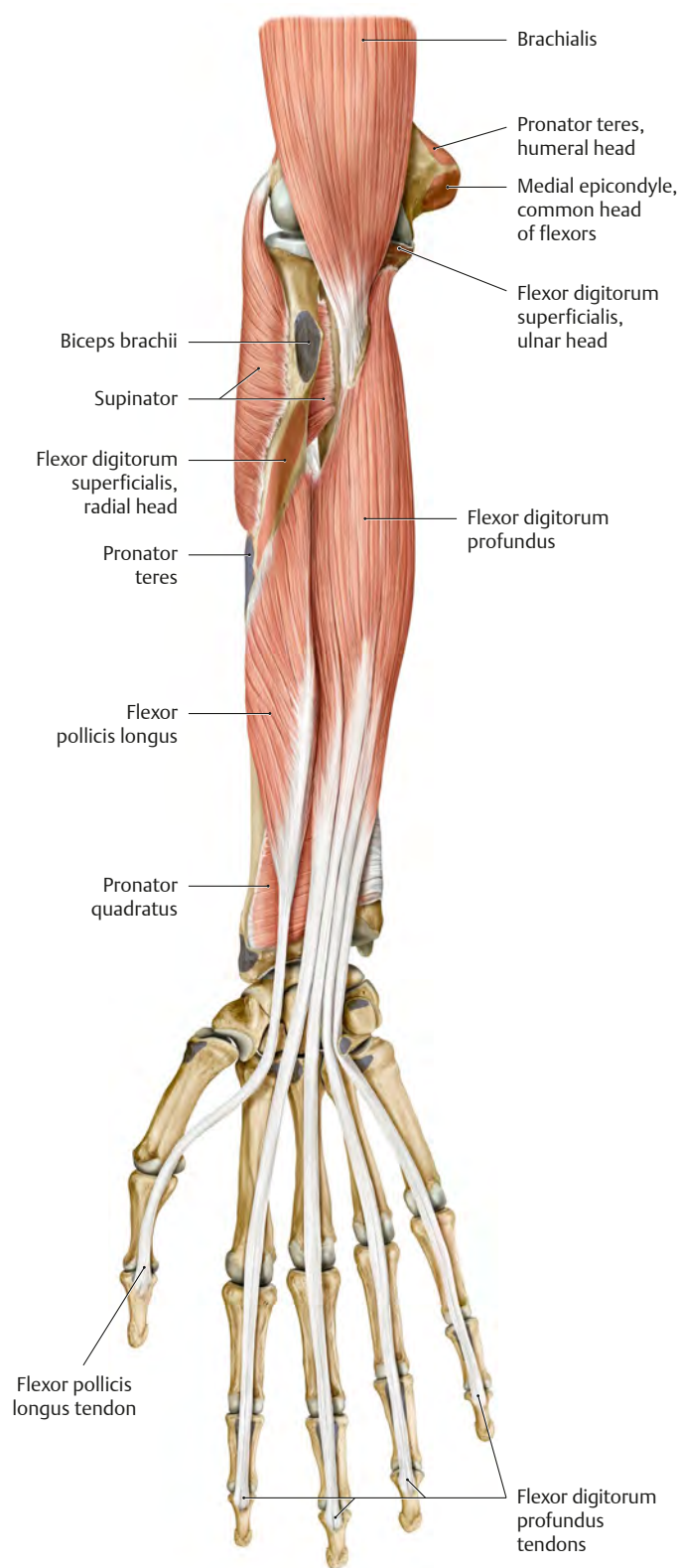
Fig. 26.10 Anterior muscles of the forearm: Dissection
 Right forearm, anterior view. Muscle origins are shown in red, insertions in blue.



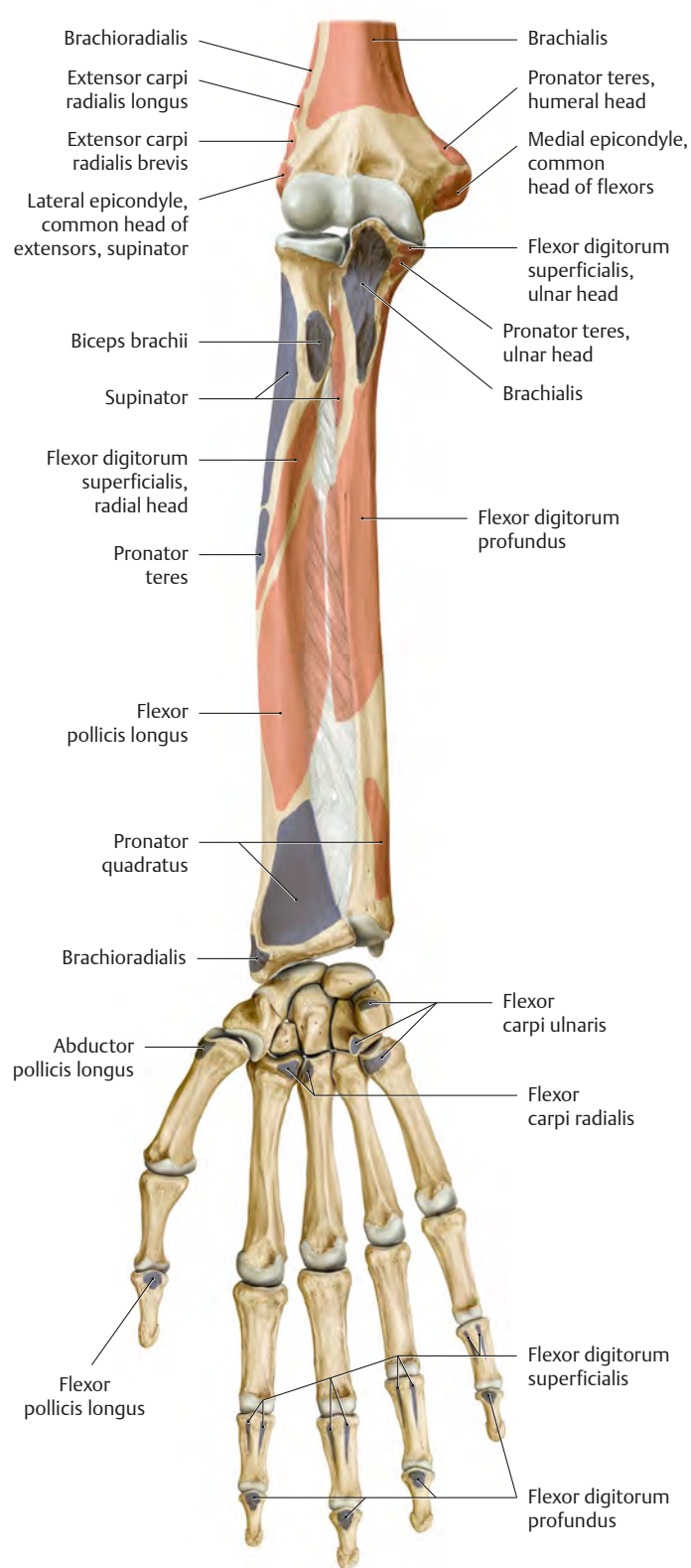
A Superficial flexors and radial muscles.



B *Removed:* Radialis muscles (brachioradialis, extensor carpi radialis longus, and extensor carpi radialis brevis), flexor carpi radialis, flexor carpi ulnaris, abductor pollicis longus, palmaris longus, and biceps brachii.



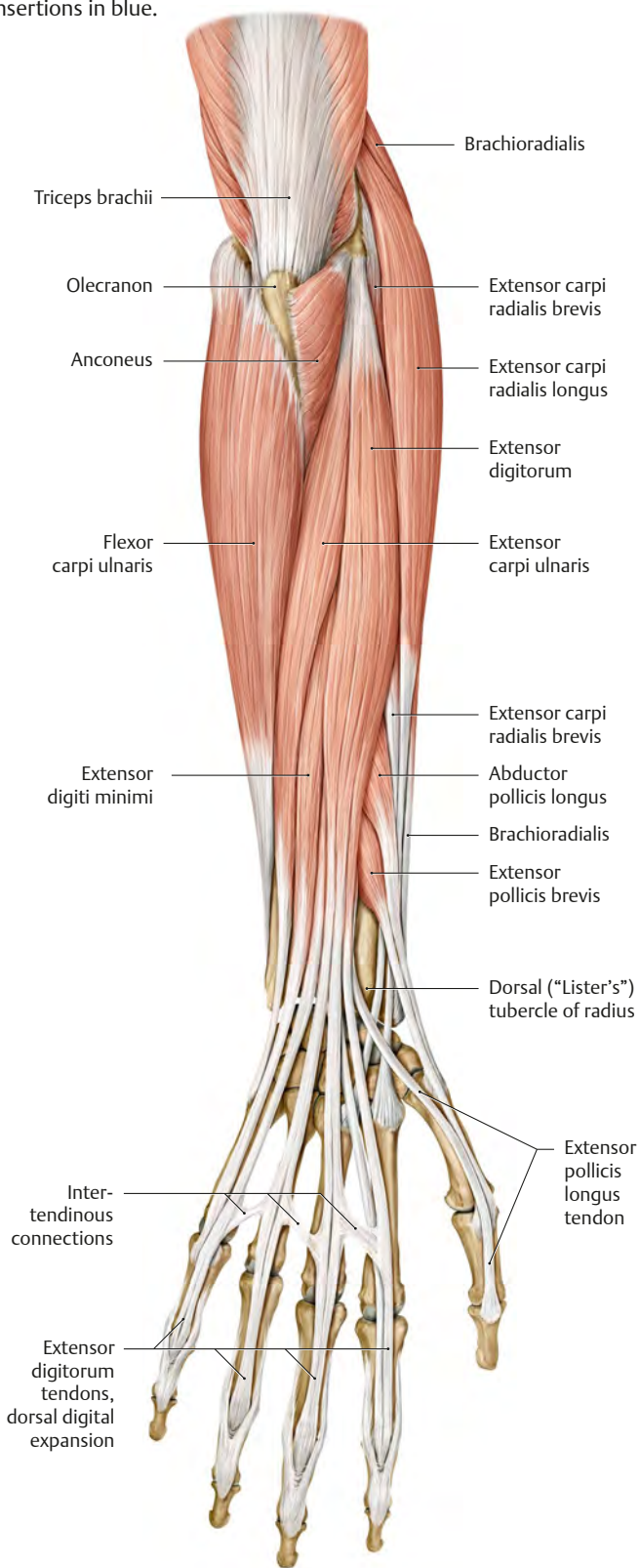
C Removed: Pronator teres and flexor digitorum superficialis.



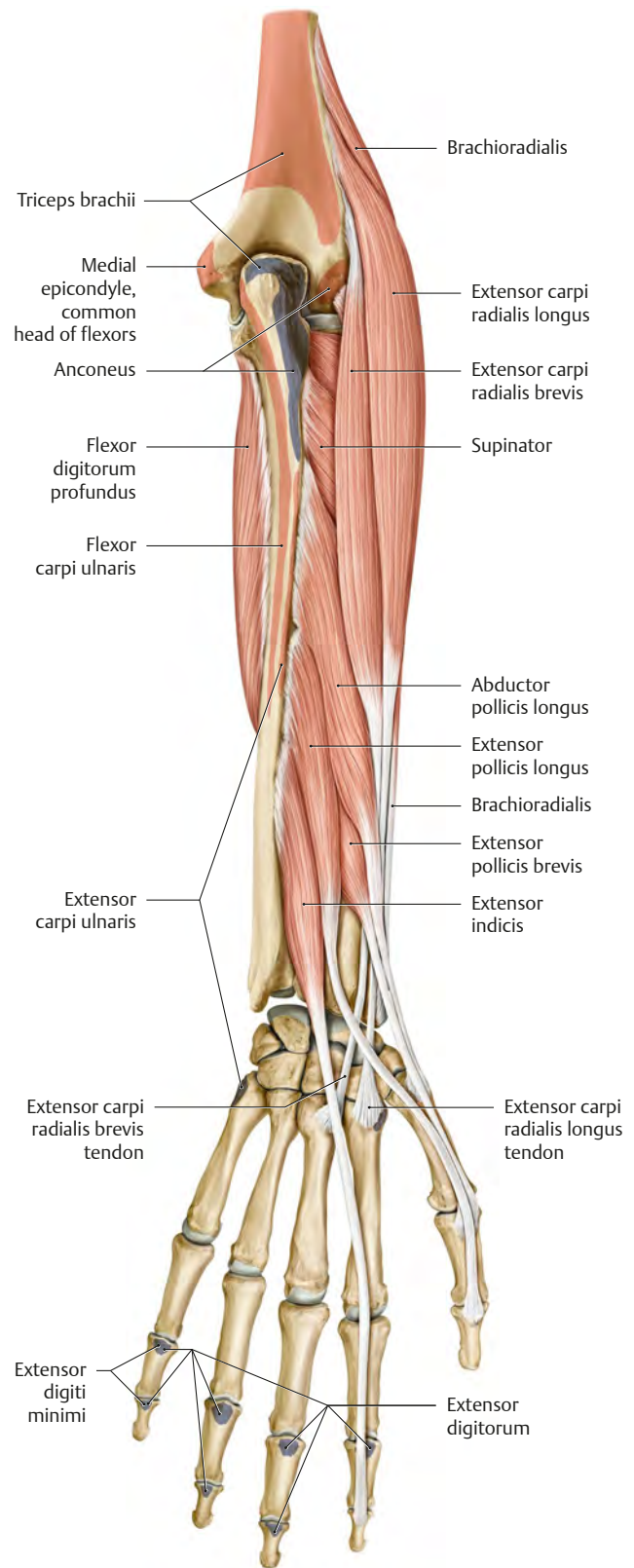
D Removed: Brachialis, supinator, pronator quadratus, and deep flexors.

Muscles of the Forearm: Posterior Compartment

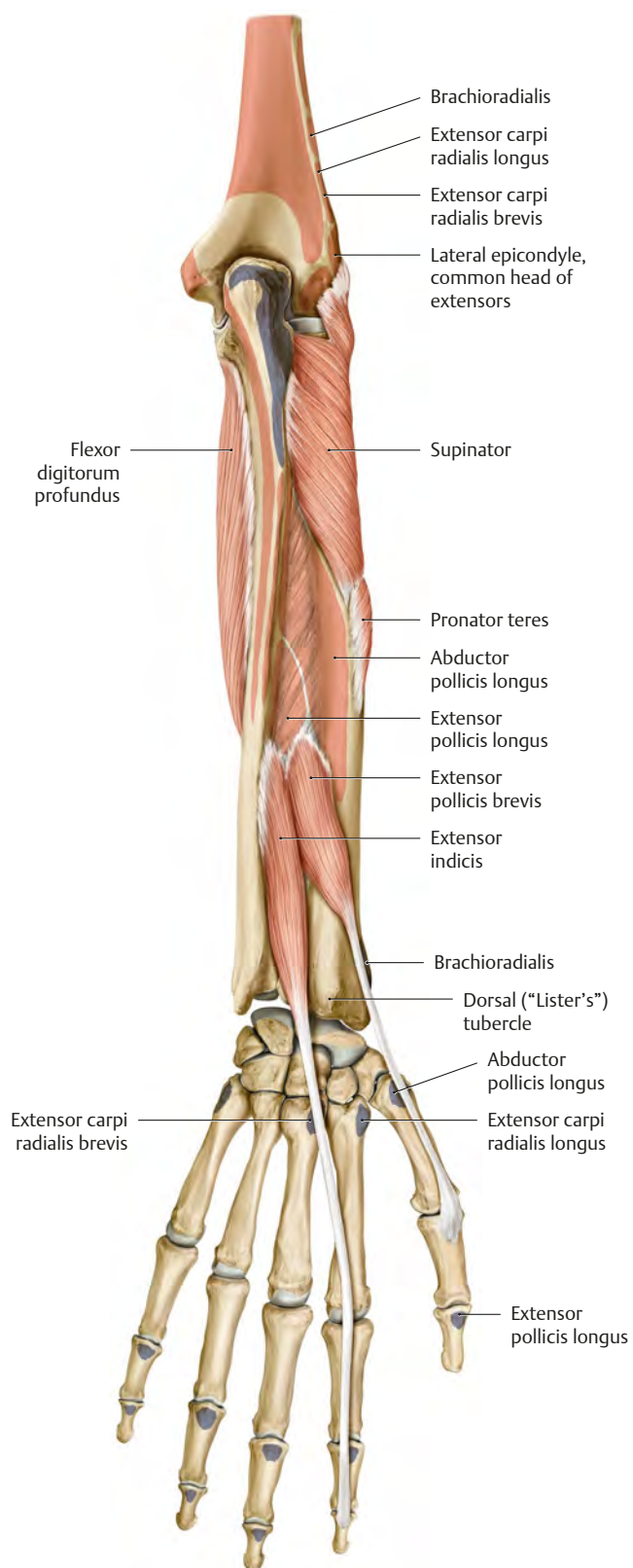
Fig. 26.11 Posterior muscles of the forearm: Dissection
 Right forearm, posterior view. Muscle origins are shown in red, insertions in blue.



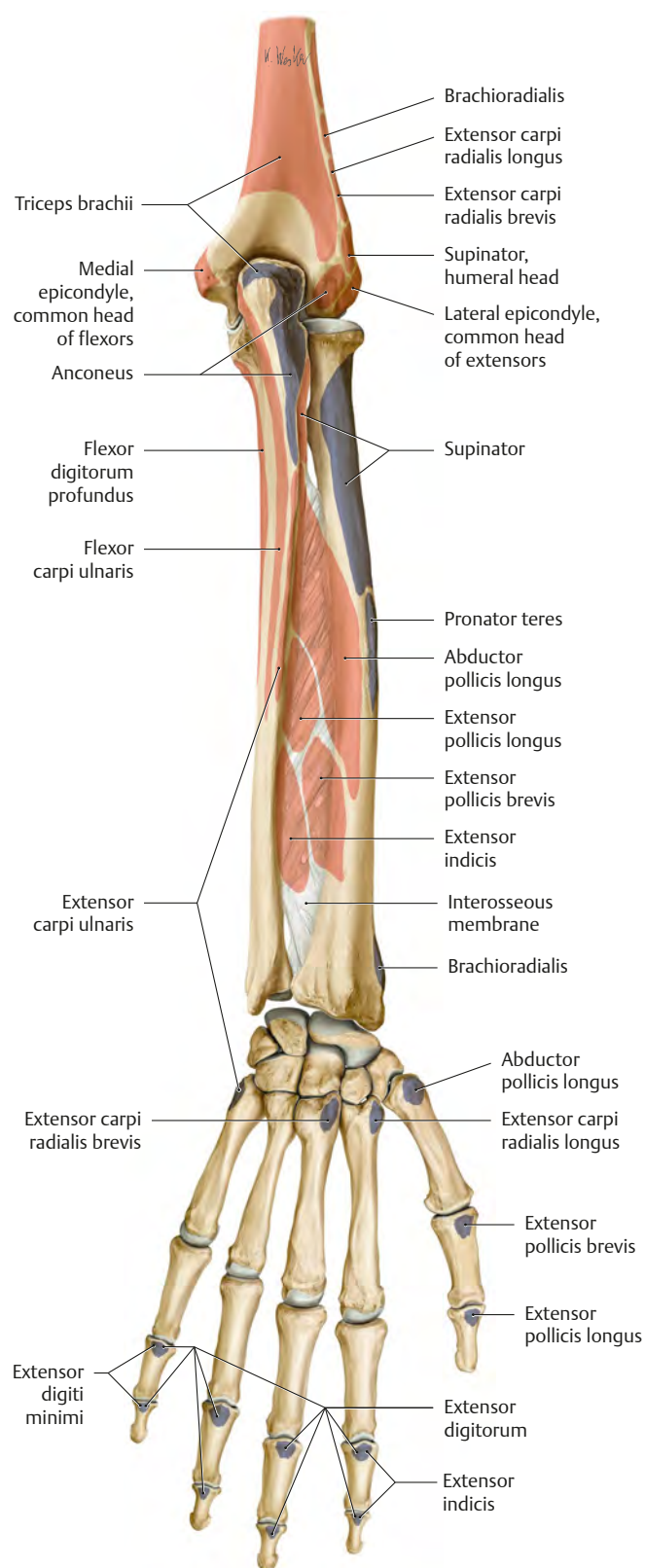
A Superficial extensors and radialis group.



B Removed: Triceps brachii, anconeus, flexor carpi ulnaris, extensor carpi ulnaris, and extensor digitorum.



C Removed: Abductor pollicis longus, extensor pollicis longus, and radialis muscles.

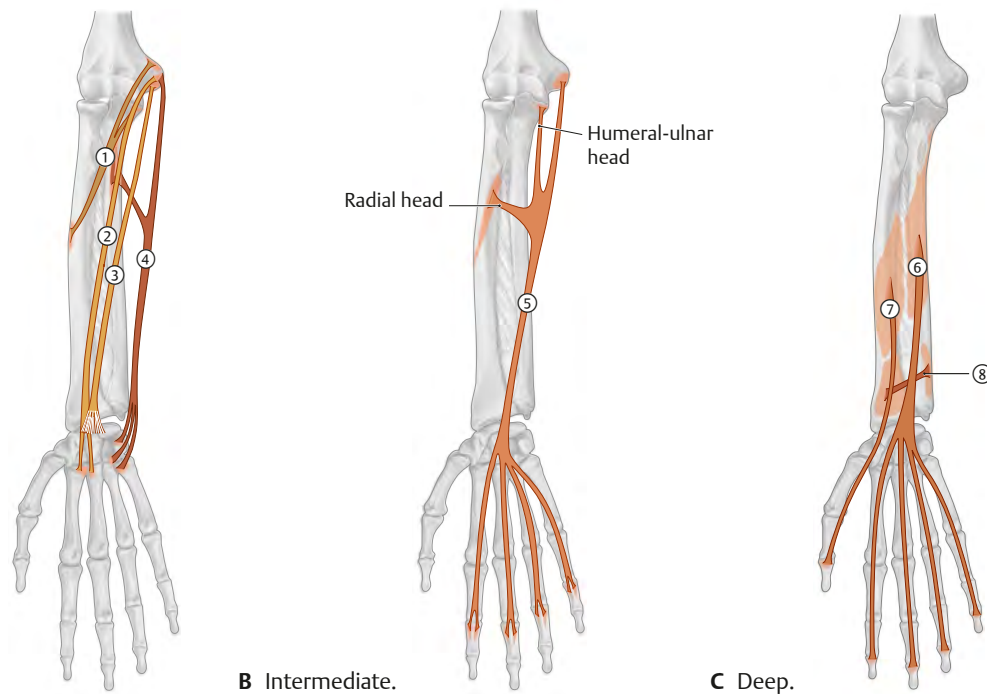


D Removed: Flexor digitorum profundus, supinator, extensor pollicis brevis, and extensor indicis.

Muscle Facts (I)

Fig. 26.12 Anterior compartment of the forearm

Right forearm, anterior view.

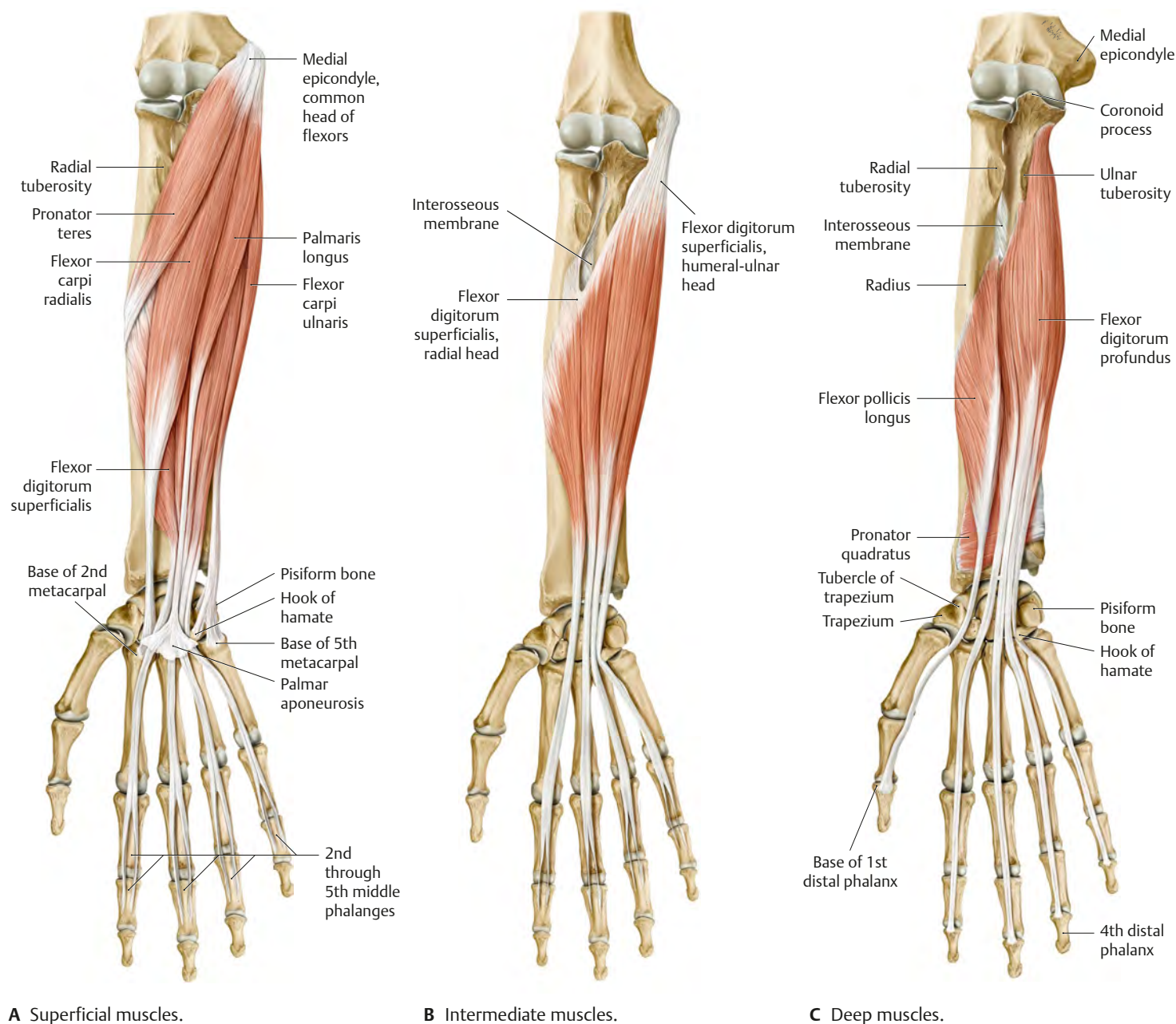
**A** Superficial.**B** Intermediate.**C** Deep.**Table 26.2****Anterior compartment of the forearm**

Muscle	Origin	Insertion	Innervation	Action
Superficial muscles				
① Pronator teres	Humeral head: medial epicondyle of humerus Ulnar head: coronoid process	Lateral radius (distal to supinator insertion)	Median n. (C6, C7)	Elbow: weak flexion Forearm: pronation
② Flexor carpi radialis	Medial epicondyle of humerus	Base of 2nd metacarpal (variance: base of 3rd metacarpal)		Wrist: flexion and abduction (radial deviation) of hand
③ Palmaris longus		Palmar aponeurosis	Median n. (C7, C8)	Elbow: weak flexion Wrist: flexion tightens palmar aponeurosis
④ Flexor carpi ulnaris	Humeral head: medial epicondyle Ulnar head: olecranon	Pisiform; hook of hamate; base of 5th metacarpal	Ulnar n. (C7–T1)	Wrist: flexion and adduction (ulnar deviation) of hand
Intermediate muscles				
⑤ Flexor digitorum superficialis	Humeral-ulnar head: medial epicondyle of humerus and coronoid process of ulna Radial head: upper half of anterior border of radius	Sides of middle phalanges of 2nd to 5th digits	Median n. (C8, T1)	Elbow: weak flexion Wrist, MCP, and PIP joints of 2nd to 5th digits: flexion
Deep muscles				
⑥ Flexor digitorum profundus	Ulna (proximal two thirds of flexor surface) and interosseous membrane	Distal phalanges of 2nd to 5th digits (palmar surface)	Median n. (C8, T1, radial half of fingers 2 and 3) Ulnar n. (C8, T1, ulnar half of fingers 4 and 5)	Wrist, MCP, PIP, and DIP joints of 2nd to 5th digits: flexion
⑦ Flexor pollicis longus	Radius (midanterior surface) and adjacent interosseous membrane	Distal phalanx of thumb (palmar surface)	Median n. (C8, T1)	Wrist: flexion and abduction (radial deviation) of hand Carpometacarpal joint of thumb: flexion MCP and IP joints of thumb: flexion
⑧ Pronator quadratus	Distal quarter of ulna (anterior surface)	Distal quarter of radius (anterior surface)		Hand: pronation Distal radioulnar joint: stabilization

DIP, distal interphalangeal; IP, interphalangeal; MCP, metacarpophalangeal; PIP, proximal interphalangeal.

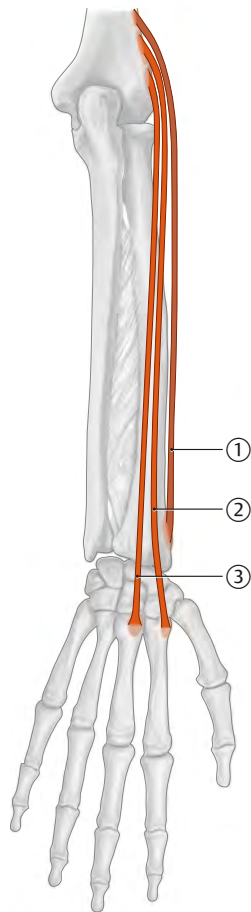
Fig. 26.13 Anterior compartment of the forearm

Right forearm, anterior view.



Muscle Facts (II)

Fig. 26.14 Posterior compartment of the forearm: Radialis muscles
Right forearm, posterior view, schematic.



Clinical box 26.4

Lateral epicondylitis

Lateral epicondylitis, or tennis elbow, involves the extensor muscles and tendons of the forearm that attach on the lateral epicondyle. The tendon most commonly involved is that of the extensor carpi radialis brevis, a muscle that helps stabilize the wrist when the elbow is extended. When the extensor carpi radialis brevis is weakened from overuse, microscopic tears form in the tendon where it attaches to the lateral epicondyle. This leads to inflammation and pain. There is some evidence that the inflammation can extend back along the tendon to the periosteum of the lateral epicondyle.

Athletes are not the only people who get tennis elbow and are actually in the minority — leading some to suggest the condition be referred to as “lateral elbow syndrome”. Workers whose activities require repetitive and vigorous use of the forearm muscles, such as common to painters, plumbers, and carpenters, are particularly prone to developing this pathology. Studies show a high incidence also among auto workers, cooks, and butchers. Common signs and symptoms of tennis elbow include pain with wrist extension against resistance, point tenderness or burning on the lateral epicondyle, and weak grip strength. Symptoms are intensified with forearm activity.

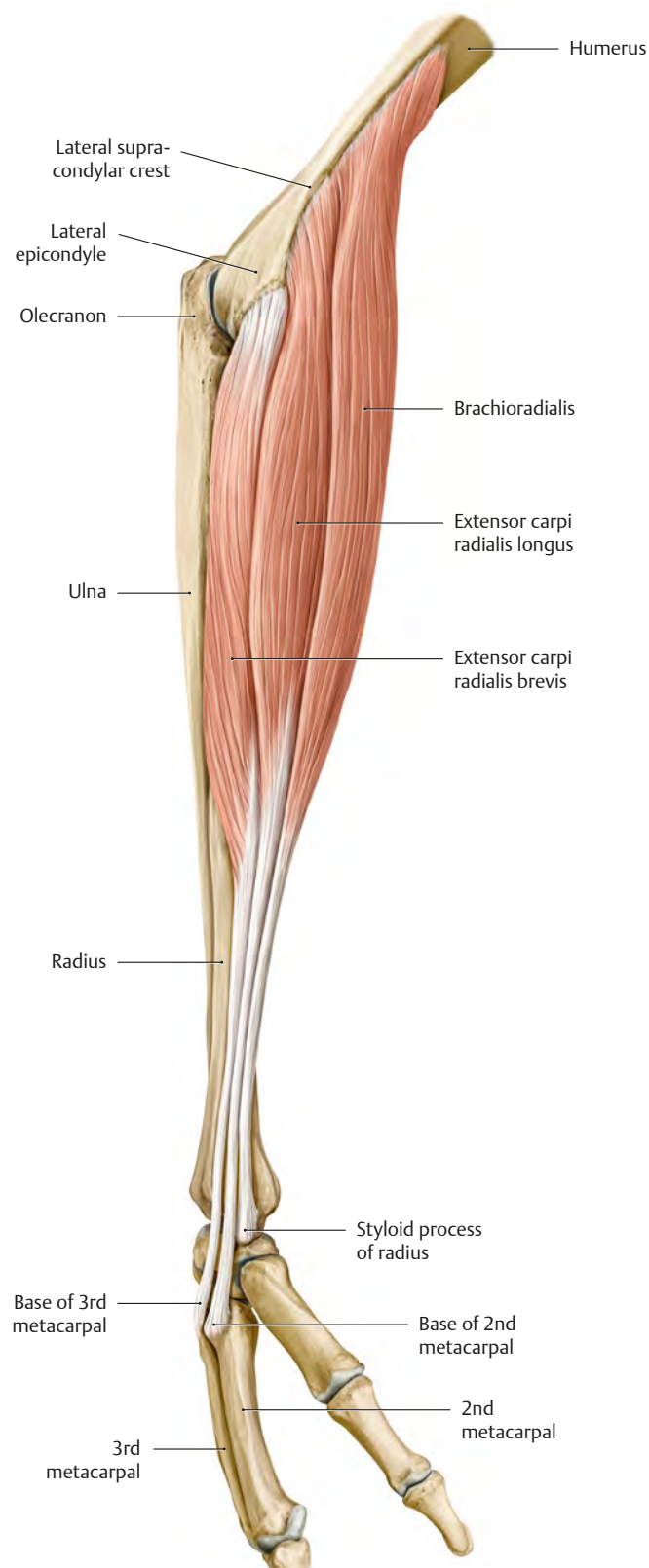
Table 26.3

Posterior compartment of the forearm: Radialis muscles

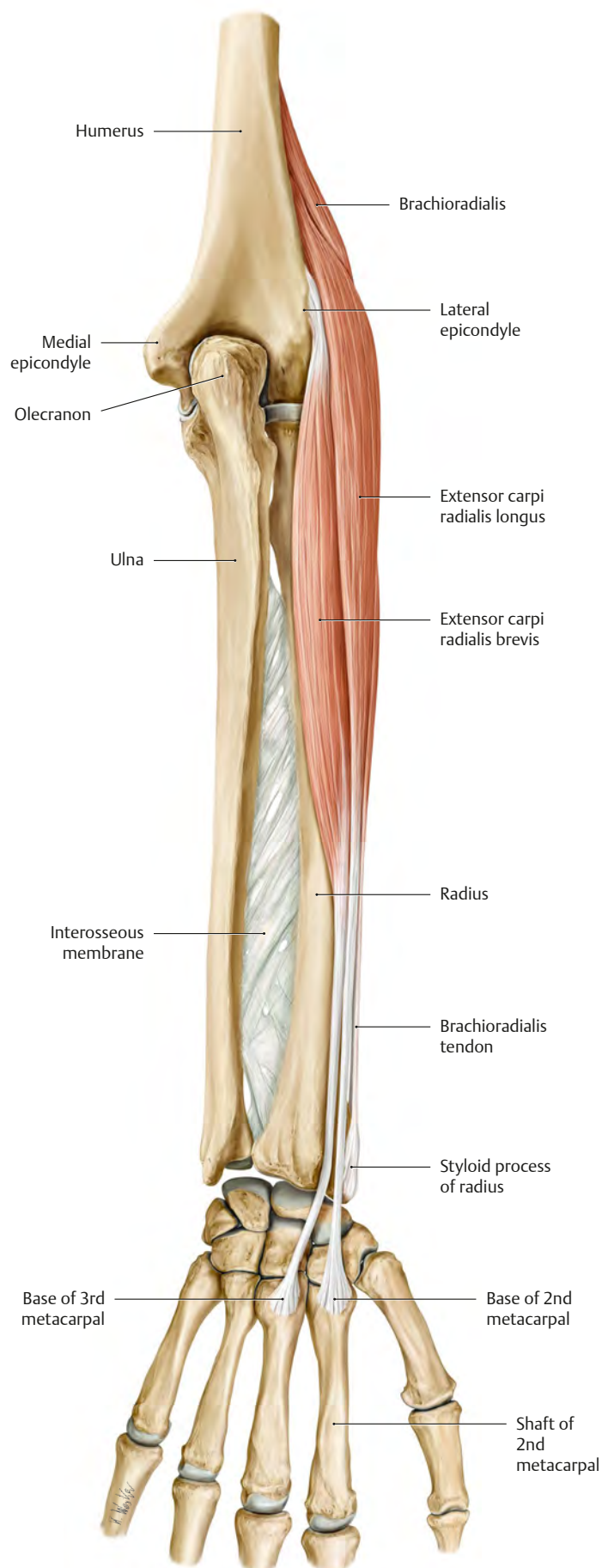
Muscle	Origin	Insertion	Innervation	Action
① Brachioradialis	Distal humerus (lateral surface), lateral intermuscular septum	Styloid process of the radius	Radial n. (C5, C6)	Elbow: flexion Forearm: semipronation
② Extensor carpi radialis longus	Lateral supracondylar ridge of distal humerus, lateral intermuscular septum	2nd metacarpal (base)	Radial n. (C6, C7)	Elbow: weak flexion Wrist: extension and abduction
③ Extensor carpi radialis brevis	Lateral epicondyle of humerus	3rd metacarpal (base)	Radial n. (C7, C8)	

Fig. 26.15 Posterior compartment of the forearm:
Radialis muscles

Right forearm.



A Lateral (radial) view.

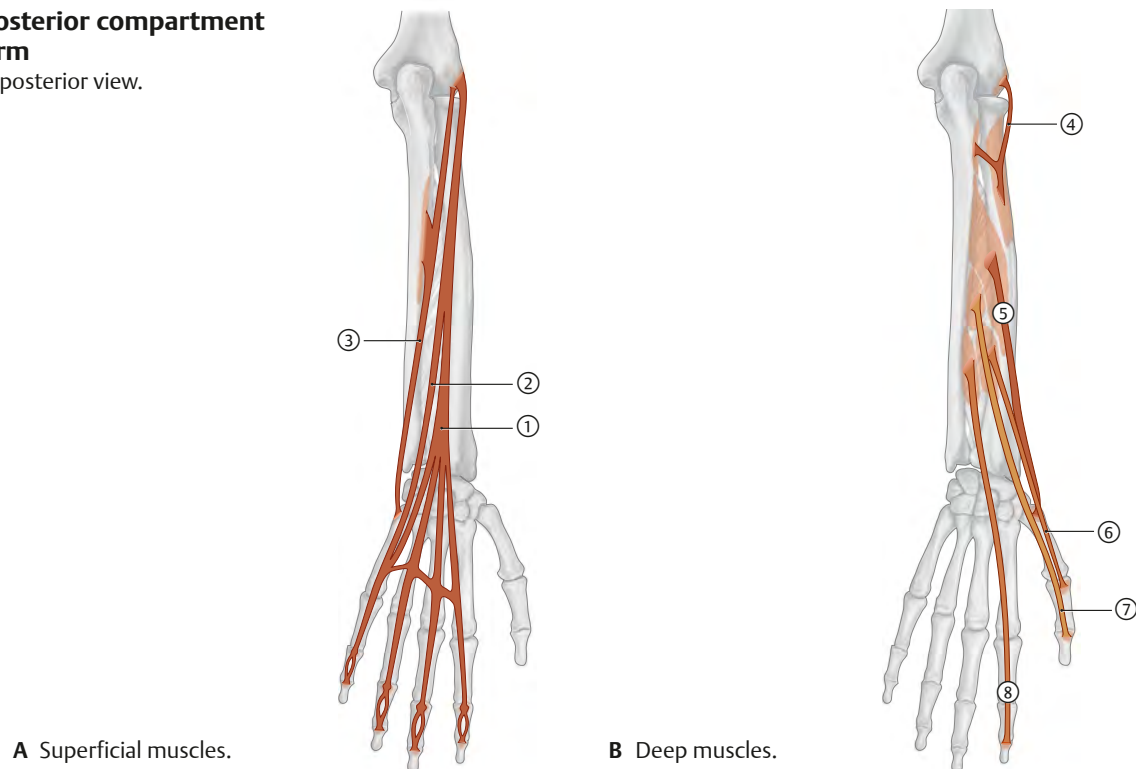


B Posterior view.

Muscle Facts (III)

Fig. 26.16 Posterior compartment of the forearm

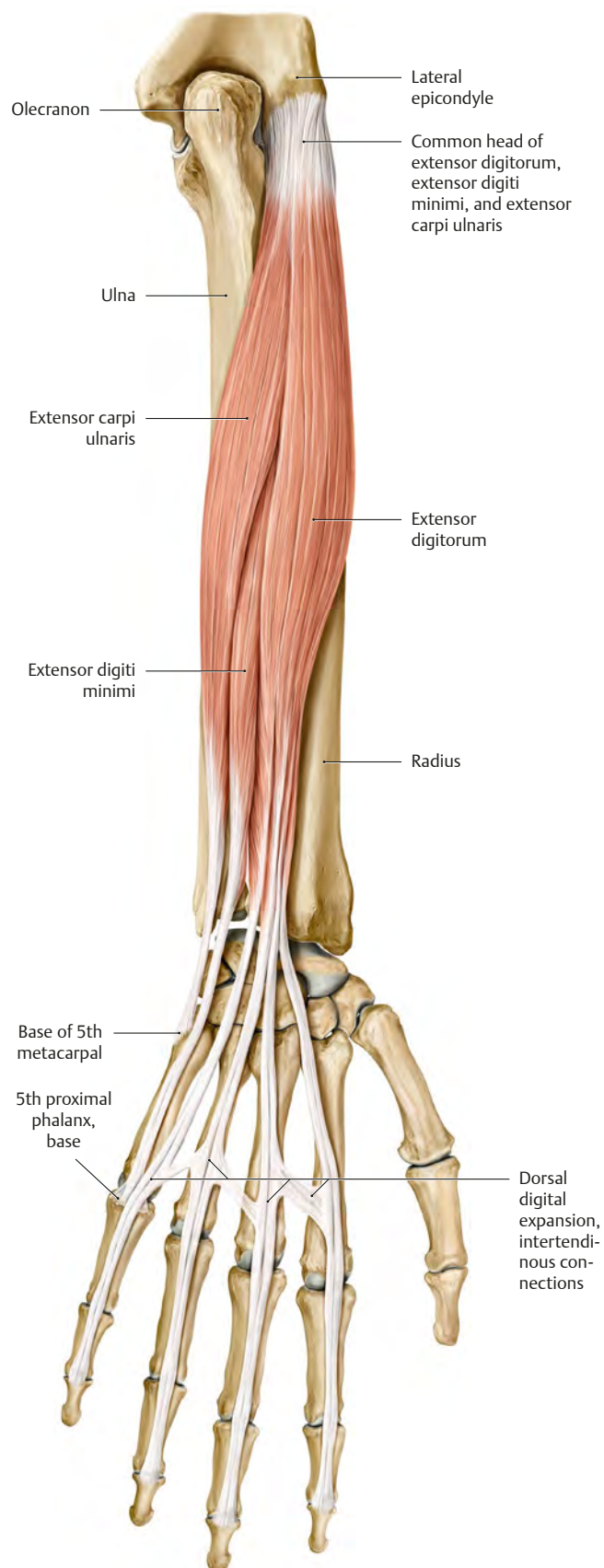
Right forearm, posterior view.

**A** Superficial muscles.**B** Deep muscles.**Table 26.4****Posterior compartment of the forearm**

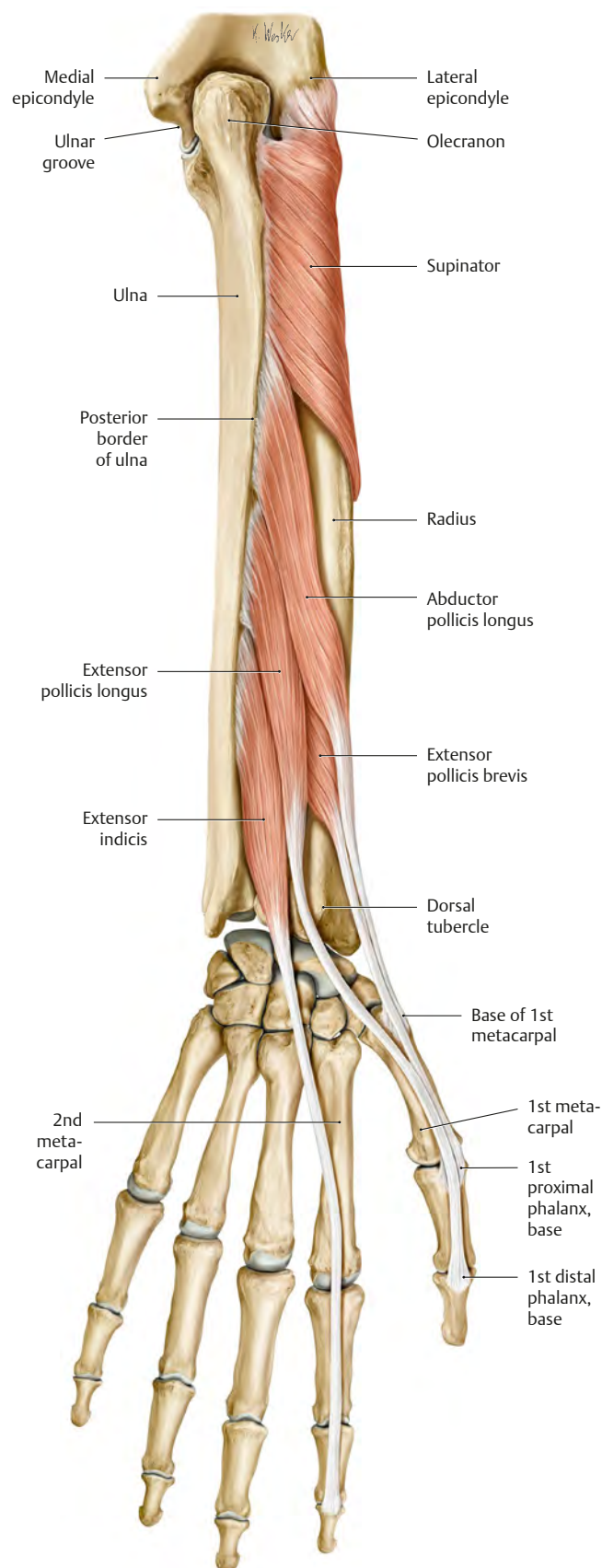
Muscle	Origin	Insertion	Innervation	Action
Superficial muscles				
① Extensor digitorum	Common head (lateral epicondyle of humerus)	Dorsal digital expansion of 2nd to 5th digits	Radial n. (C7, C8)	Wrist: extension MCP, PIP, and DIP joints of 2nd to 5th digits: extension/abduction of fingers
② Extensor digiti minimi		Dorsal digital expansion of 5th digit		Wrist: extension, ulnar abduction of hand MCP, PIP, and DIP joints of 5th digit: extension and abduction of 5th digit
③ Extensor carpi ulnaris	Common head (lateral epicondyle of humerus) Ulnar head (dorsal surface)	Base of 5th metacarpal		Wrist: extension, adduction (ulnar deviation) of hand
Deep muscles				
④ Supinator	Olecranon, lateral epicondyle of humerus, radial collateral ligament, annular ligament of radius	Radius (between radial tuberosity and insertion of pronator teres)	Radial n. (C6, C7)	Radioulnar joints: supination
⑤ Abductor pollicis longus	Radius and ulna (dorsal surfaces, interosseous membrane)	Base of 1st metacarpal	Radial n. (C7, C8)	Radiocarpal joint: abduction of the hand Carpometacarpal joint of thumb: abduction
⑥ Extensor pollicis brevis	Radius (posterior surface) and interosseous membrane	Base of proximal phalanx of thumb		Radiocarpal joint: abduction (radial deviation) of hand Carpometacarpal and MCP joints of thumb: extension
⑦ Extensor pollicis longus	Ulna (posterior surface) and interosseous membrane	Base of distal phalanx of thumb		Wrist: extension and abduction (radial deviation) of hand Carpometacarpal joint of thumb: adduction MCP and IP joints of thumb: extension
⑧ Extensor indicis	Ulna (posterior surface) and interosseous membrane	Posterior digital extension of 2nd digit		Wrist: extension MCP, PIP, and DIP joints of 2nd digit: extension
DIP, distal interphalangeal; IP, interphalangeal; MCP, metacarpophalangeal; PIP, proximal interphalangeal.				

Fig. 26.17 Posterior compartment of the forearm:
Superficial and deep muscles

Right forearm, posterior view.



A Superficial extensors.



B Deep extensors with supinator.

27 Wrist & Hand

Bones of the Wrist & Hand

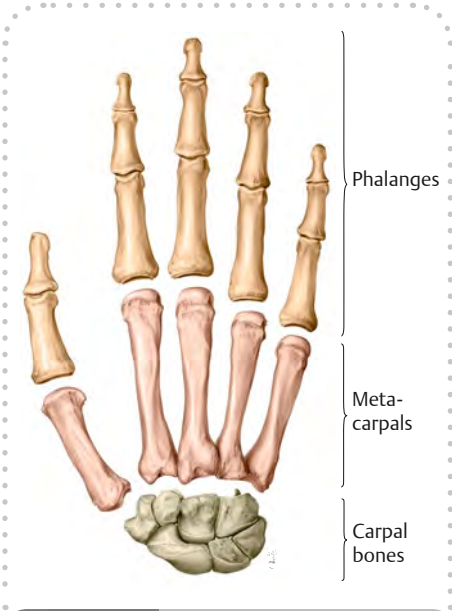


Table 27.1 Bones of the wrist and hand	
Phalanges	1st to 5th proximal phalanges
	2nd to 5th middle phalanges*
	1st to 5th distal phalanges
Metacarpal bones	1st to 5th metacarpals
Carpal bones	Trapezium Scaphoid
	Trapezoid Lunate
	Capitate Triquetrum
	Hamate Pisiform

*There are only four middle phalanges (the thumb has only a proximal and a distal phalanx).

Fig. 27.1 Dorsal view
Right hand.

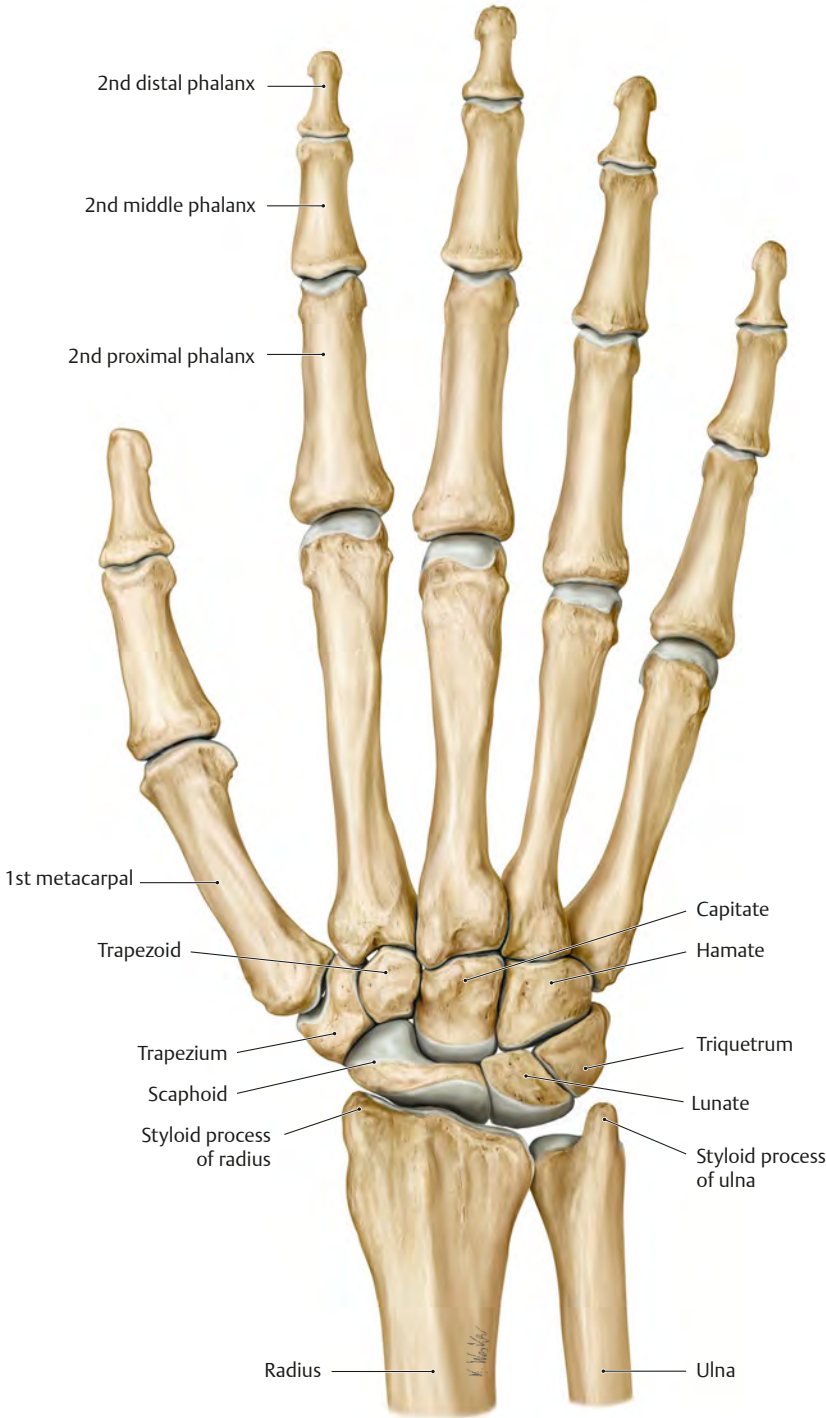


Fig. 27.2 Palmar view
Right hand.

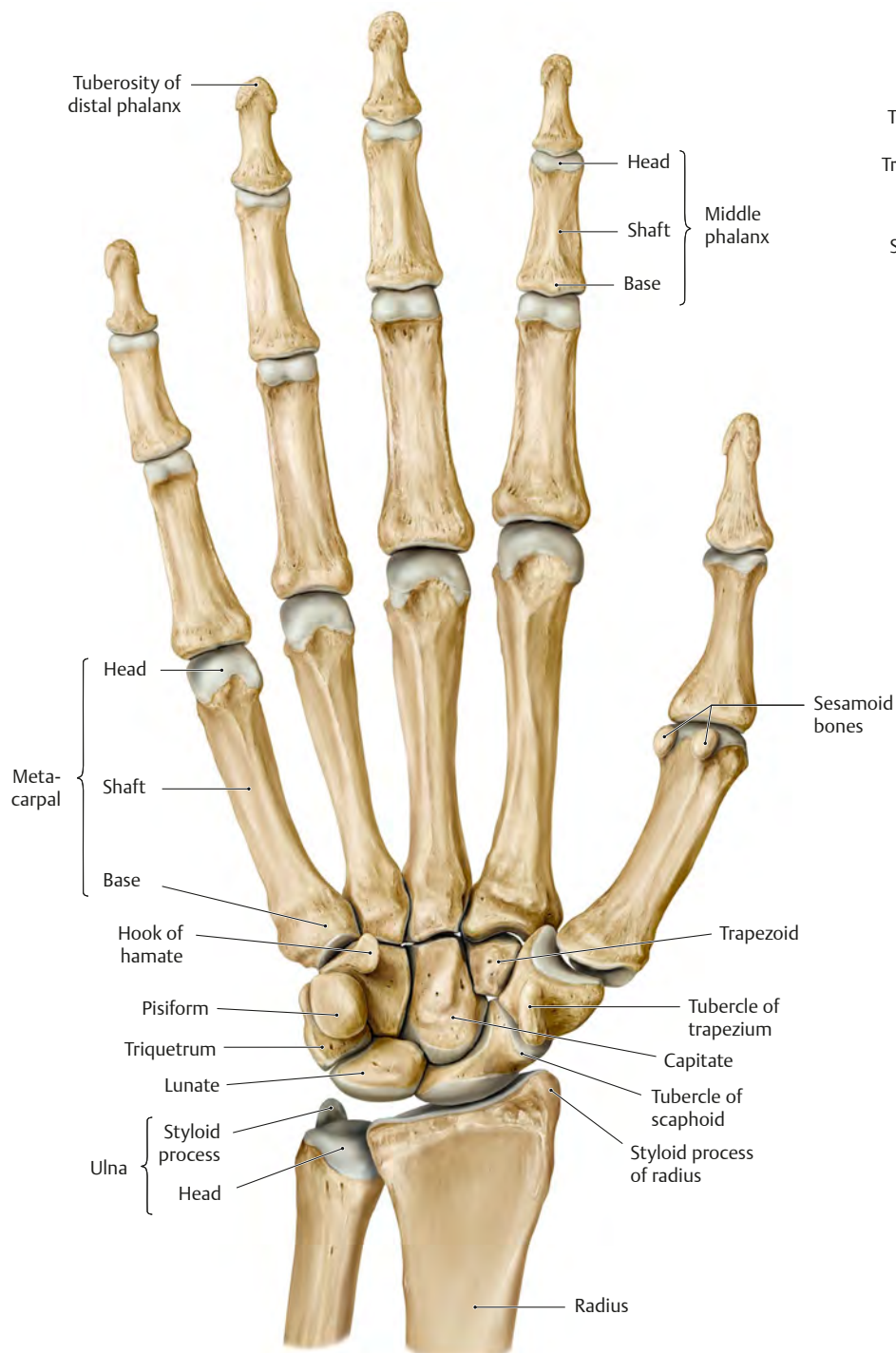
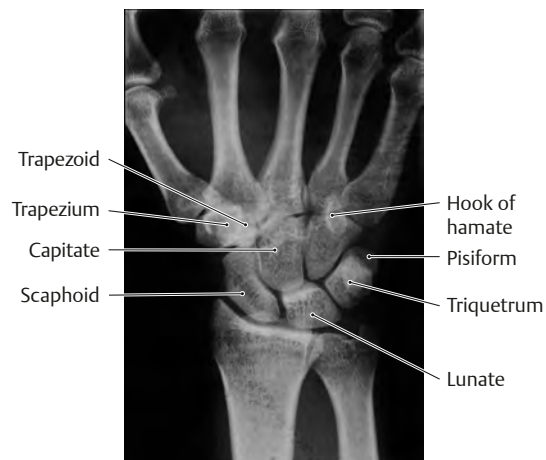


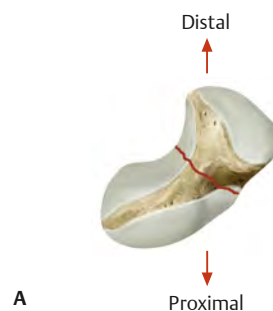
Fig. 27.3 Radiograph of the wrist
Anteroposterior view of left limb.



Clinical box 27.1

Scaphoid Fractures

Scaphoid fractures are the most common carpal bone fractures, generally occurring at the narrowed waist between the proximal and distal poles (**A**, right scaphoid red line; **B**, white arrow). Because blood supply to the scaphoid is transmitted via the distal segment, fractures at the waist can compromise the supply to the proximal segment, often resulting in nonunion and avascular necrosis.

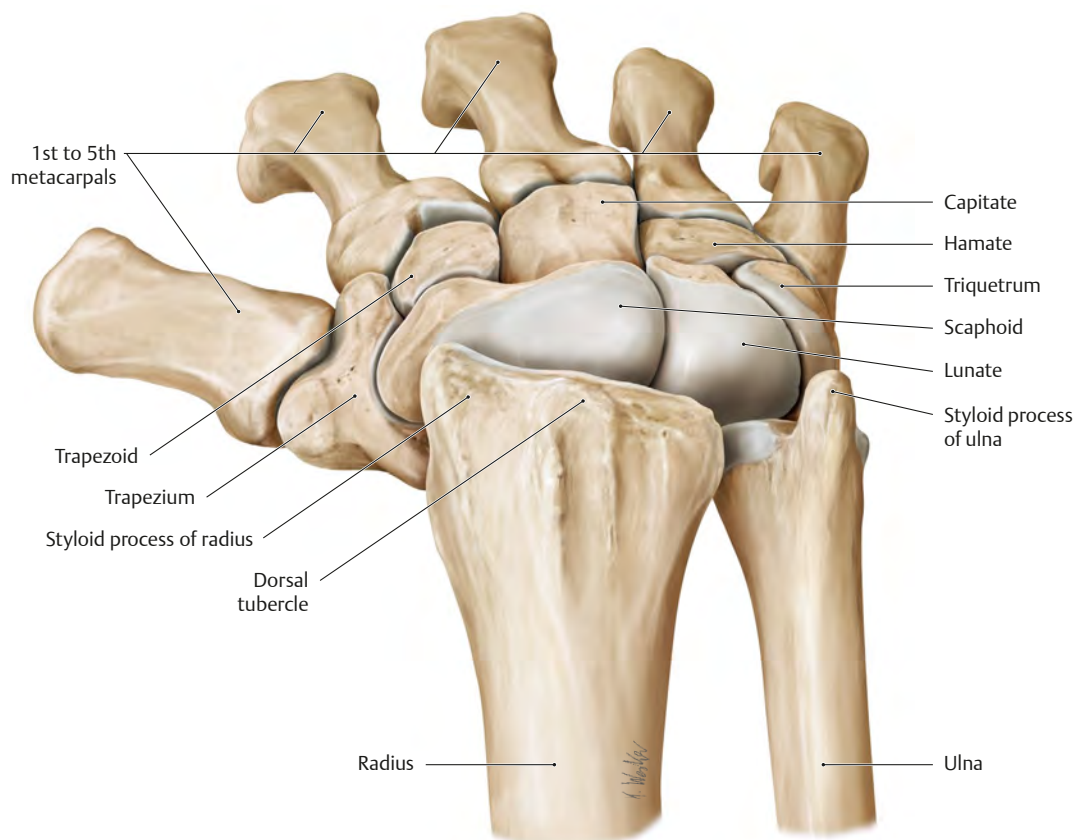


A

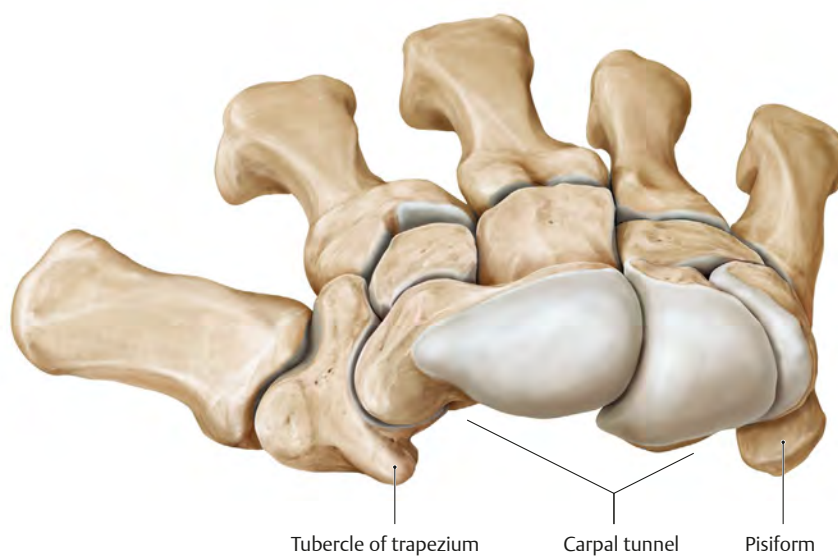


B

Fig. 27.4 Carpal bones of the right wrist

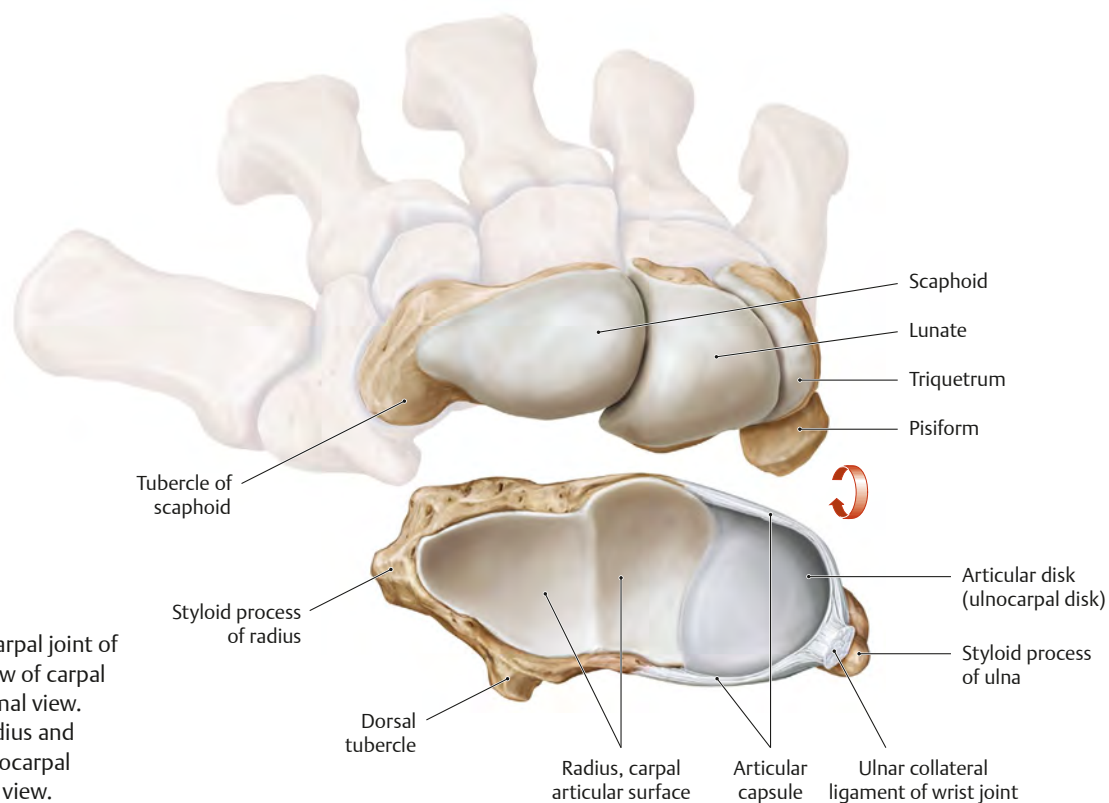


A Carpal bones of the right wrist with the wrist in flexion, proximal view.

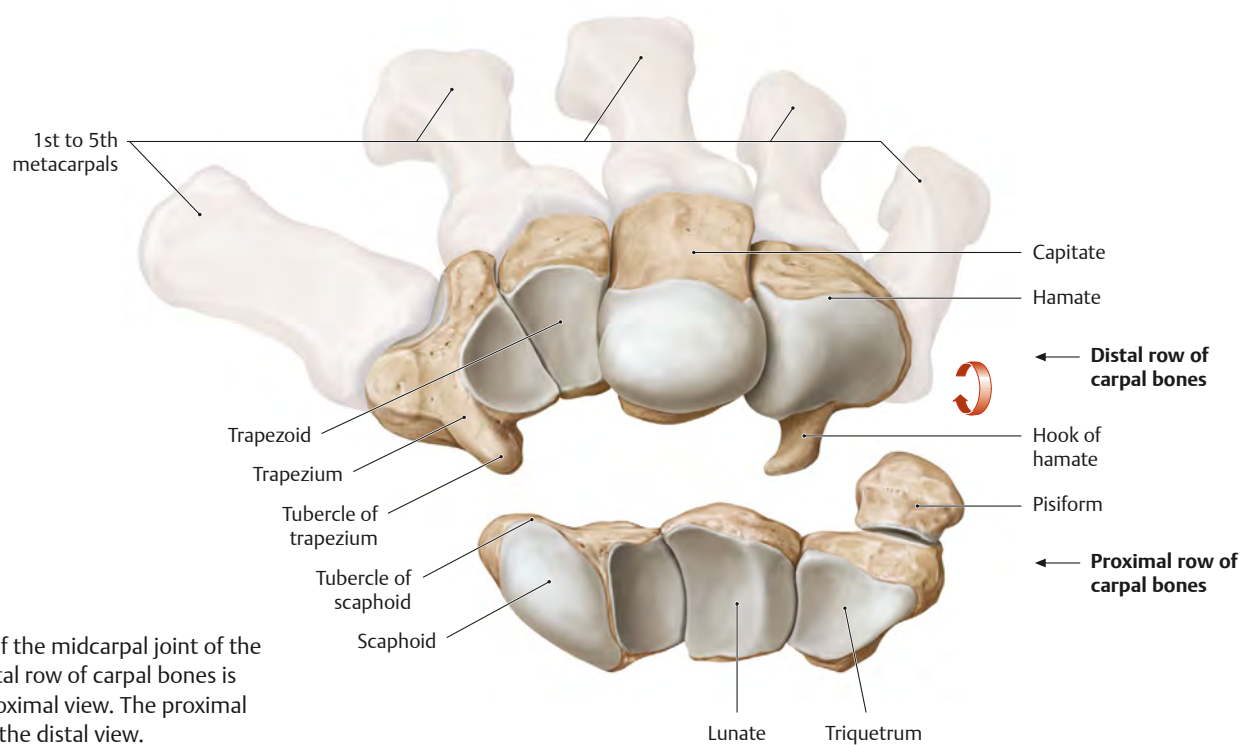


B Carpal and metacarpal bones of the right wrist with radius and ulna removed, proximal view.

C Articular surfaces of the radiocarpal joint of the right wrist. The proximal row of carpal bones is shown from the proximal view. The articular surfaces of the radius and ulna, and the articular disk (ulnocarpal disk) are shown from the distal view.

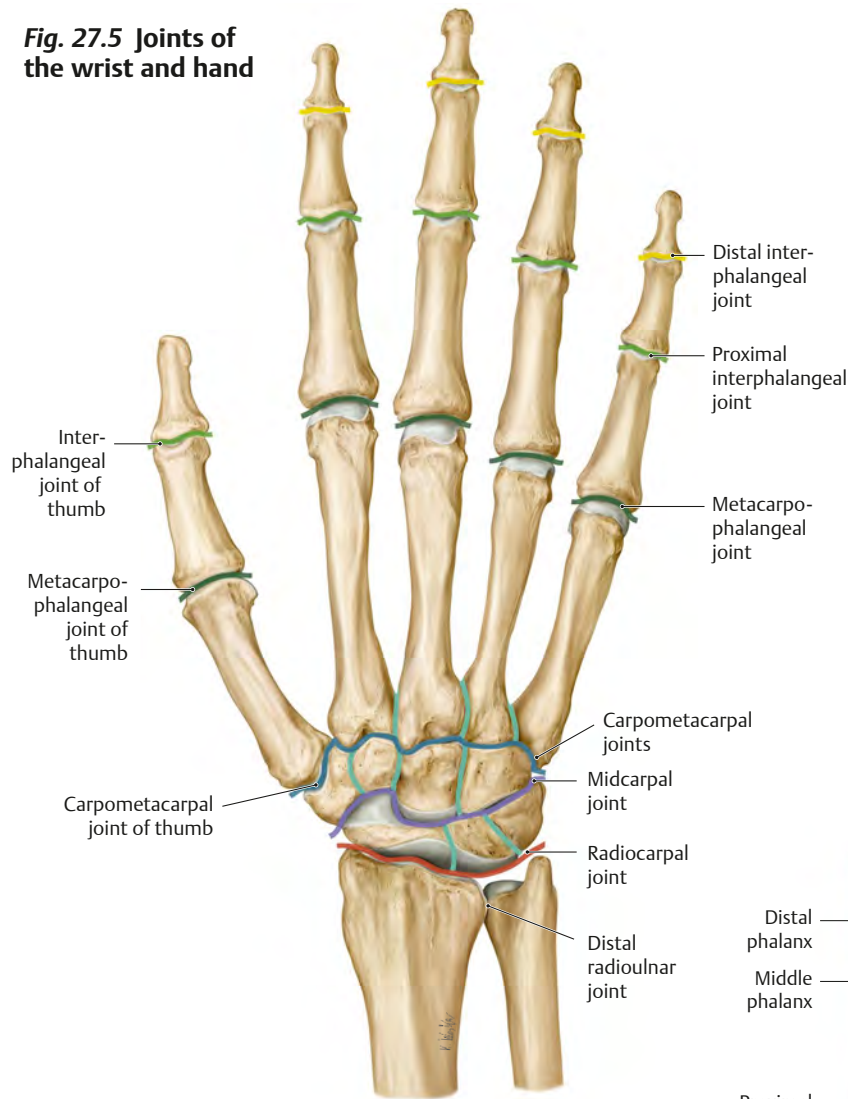


D Articular surfaces of the midcarpal joint of the right wrist. The distal row of carpal bones is shown from the proximal view. The proximal row is shown from the distal view.



Joints of the Wrist & Hand

Fig. 27.5 Joints of the wrist and hand

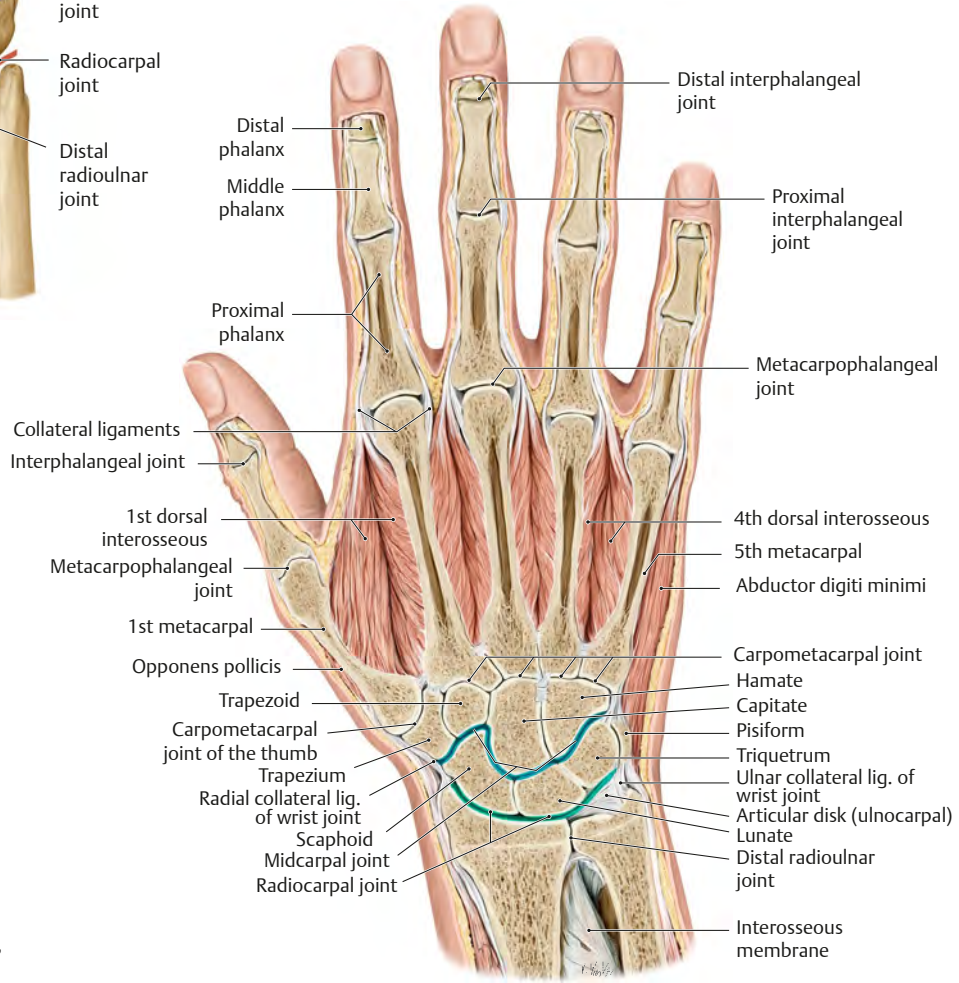


A Right hand, posterior (dorsal) view.

Clinical box 27.2

Abduction and adduction at the metacarpophalangeal joint

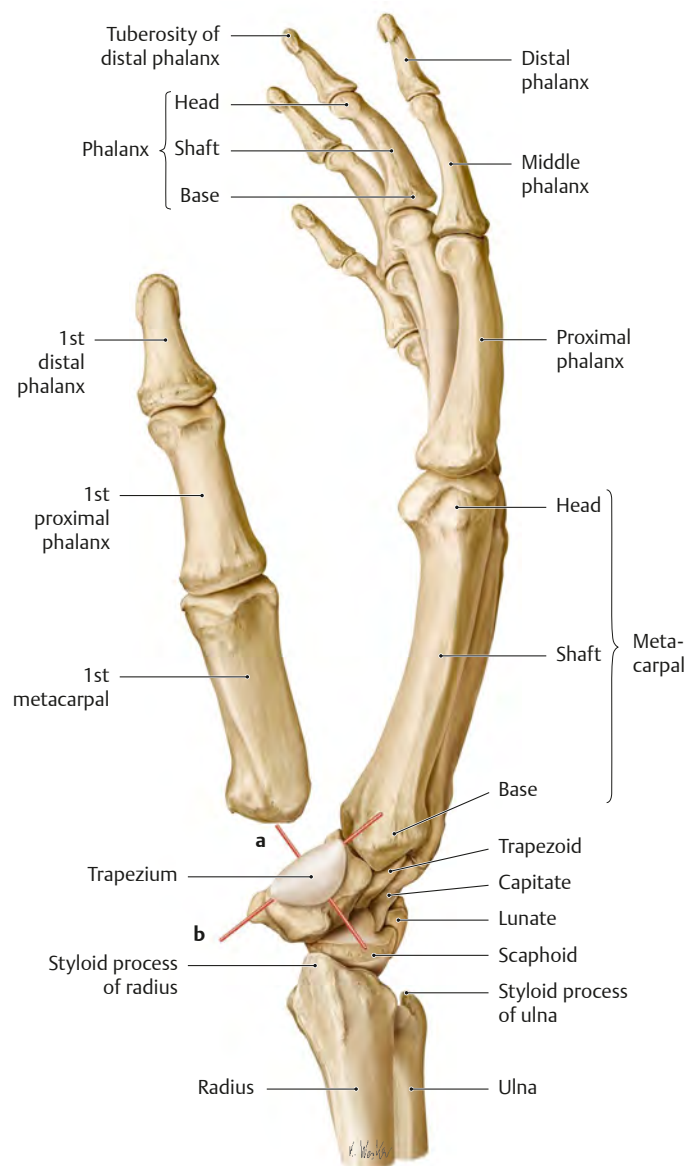
Abduction and adduction movements are described in relation to the middle finger: all movements away from the middle finger are classified as abduction, all movements toward the middle finger as adduction.



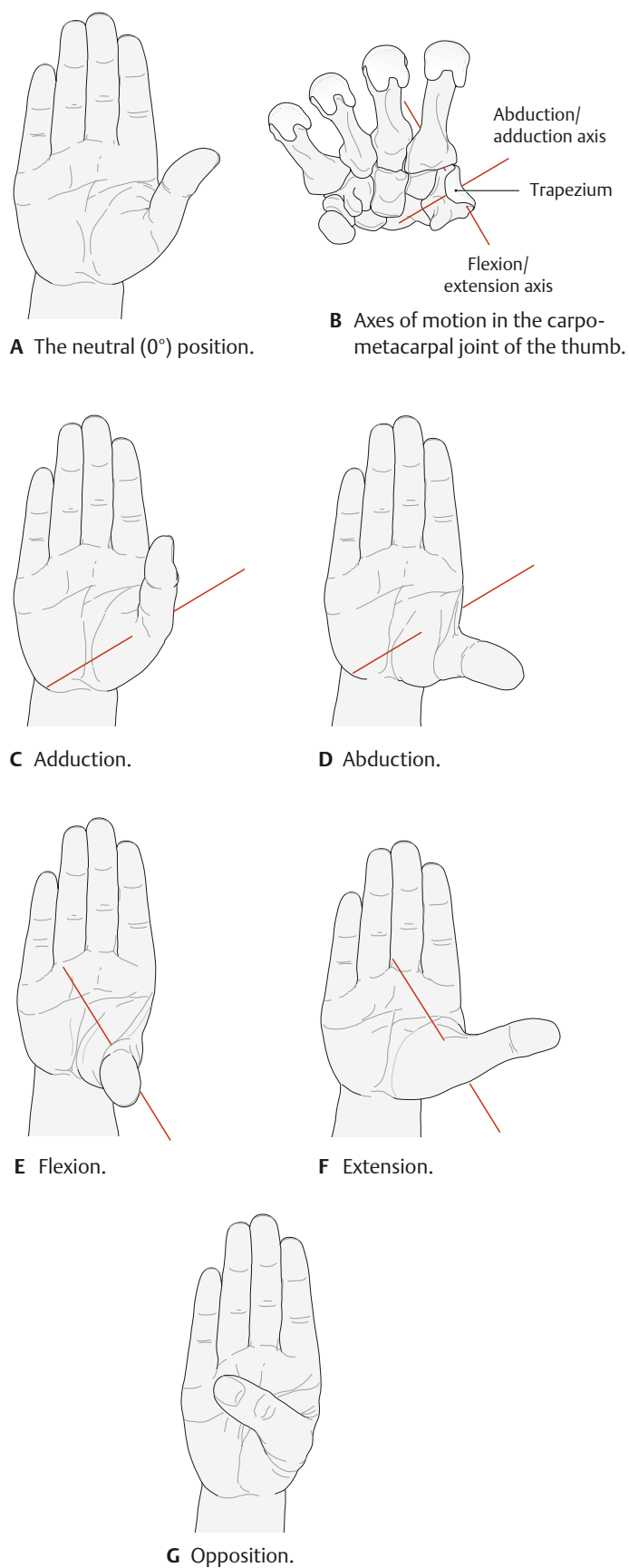
B Coronal section. Right hand, posterior (dorsal) view.

Fig. 27.6 Carpometacarpal joint of the thumb

Right hand, radial view. The 1st metacarpal bone has been moved slightly distally to expose the articular surface of the trapezium. Two cardinal axes of motion are shown here: (a) abduction/adduction and (b) flexion/extension.

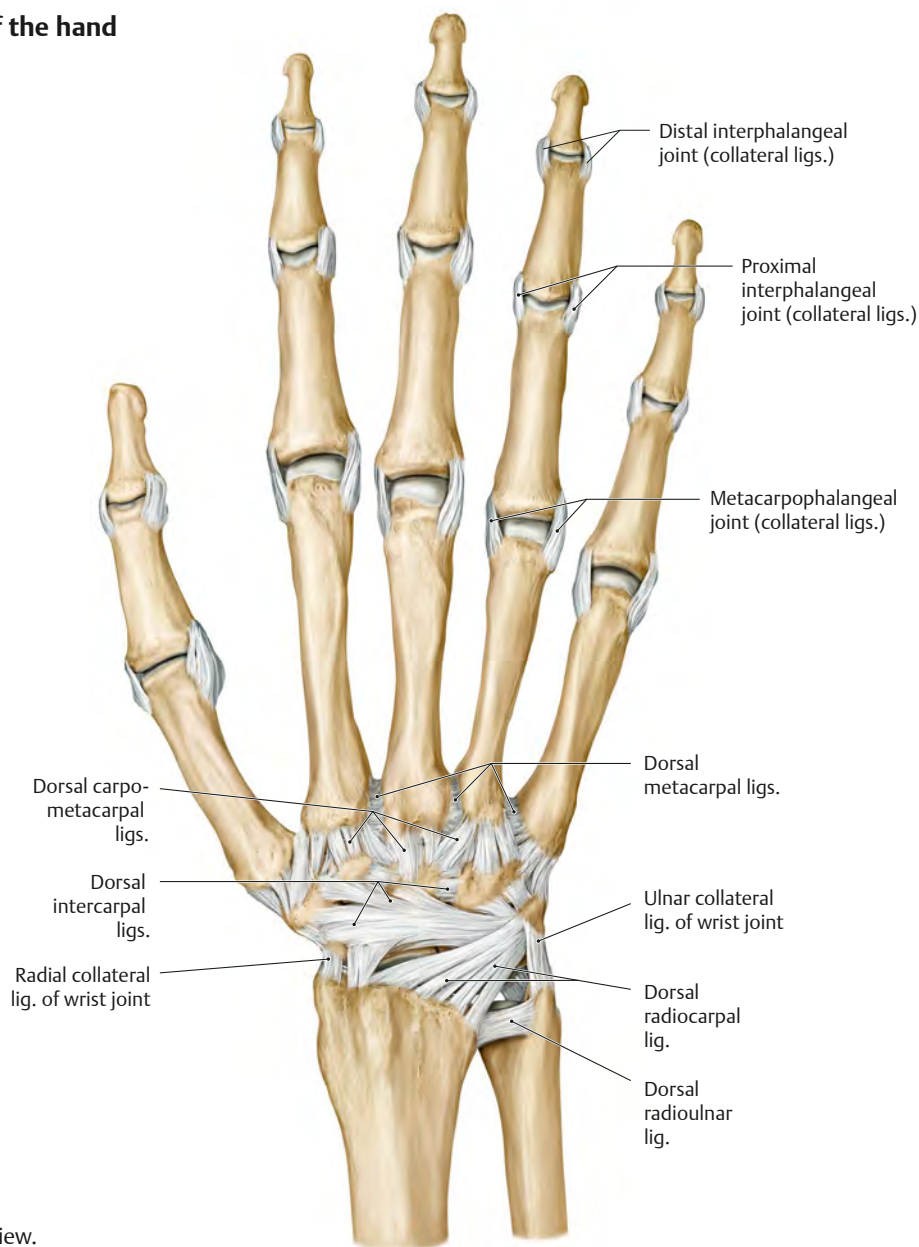
**Fig. 27.7 Movements of the carpometacarpal joint of the thumb**

Right hand, Palmar view.



Ligaments of the Hand

Fig. 27.8 Ligaments of the hand
Right hand.



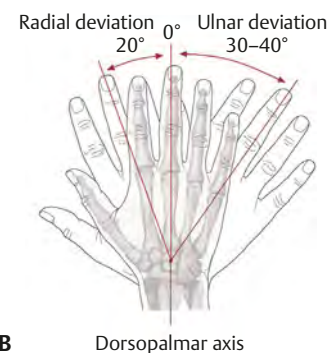
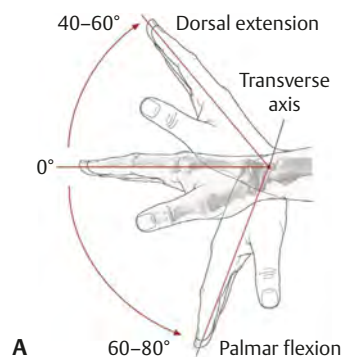
A Posterior (dorsal) view.

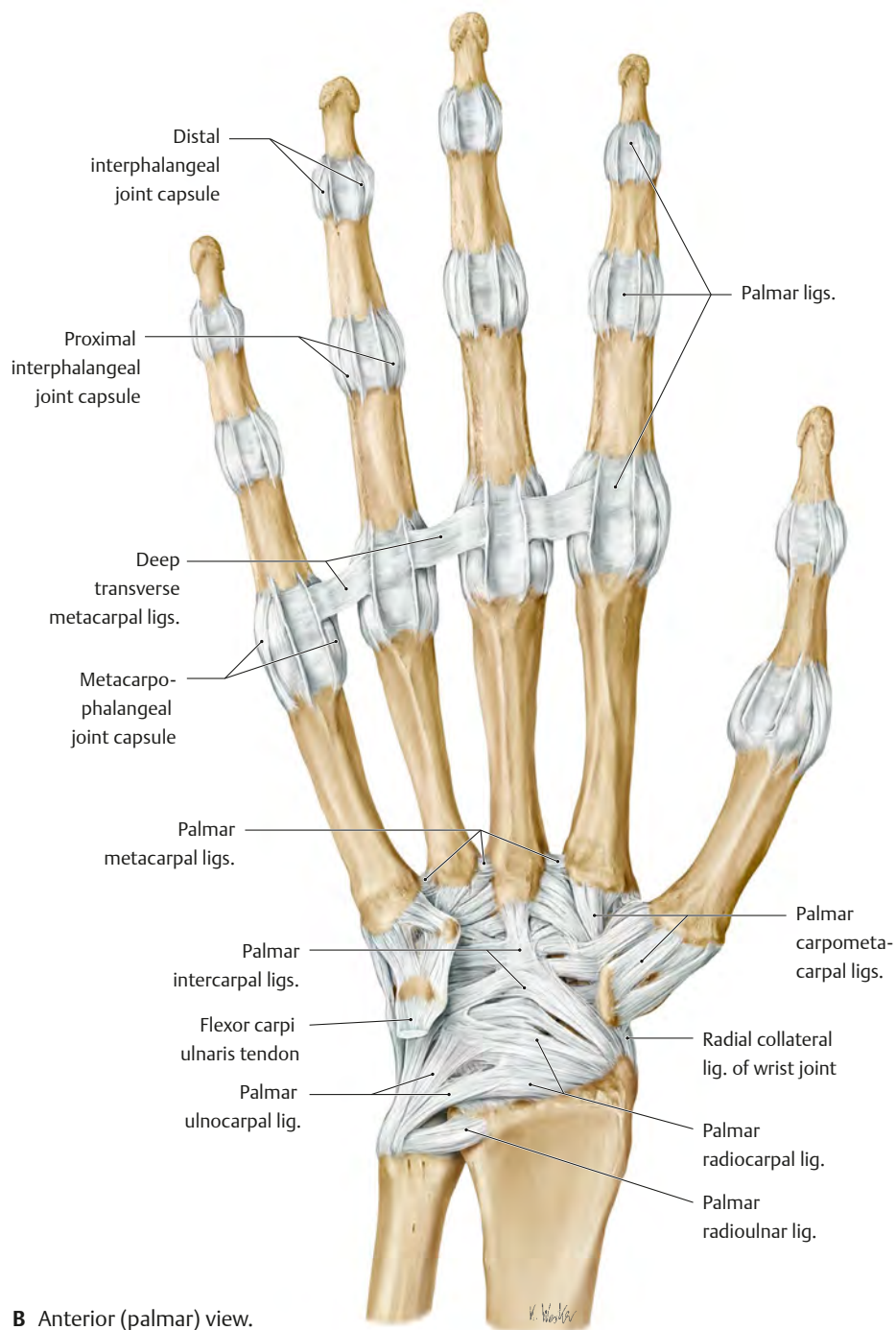


Clinical box 27.3

Movements at the radiocarpal and midcarpal joints

Palmar flexion and dorsal extension occur around a transverse axis (**A**) that runs through the lunate bone (radiocarpal joint) and capitate bone (midcarpal joint). Radial and ulnar deviation (**B**) occur around a dorsopalmar axis that runs through the capitate bone.





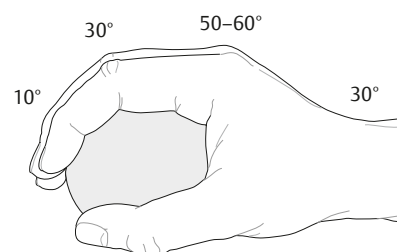
B Anterior (palmar) view.
Cut: Flexor retinaculum.



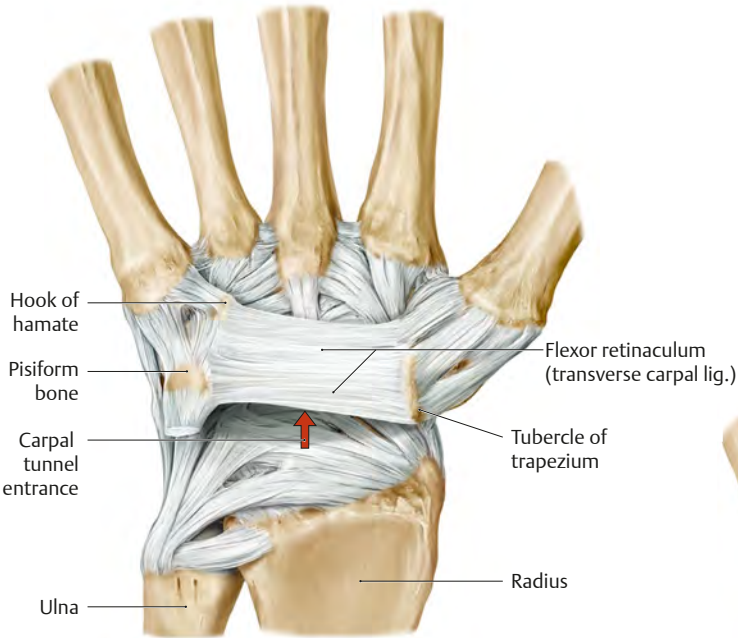
Clinical box 27.4

Functional position of the hand

The anatomic position of the hand, in which the palm is flat, the fingers are extended, and the forearm is supinated (palm facing forward), differs from the normal relaxed position of the hand. At rest, the forearm is in mid-supination/pronation (palm facing the body), the wrist is slightly extended, the fingers form an arcade of flexion, and the thumb is in the neutral position. Postoperative immobilization of the hand (by a cast or splint) fixes the fingers in flexion and the wrist in extension to prevent shortening of the ligaments and to maintain the ability of the hand to assume normal resting position.

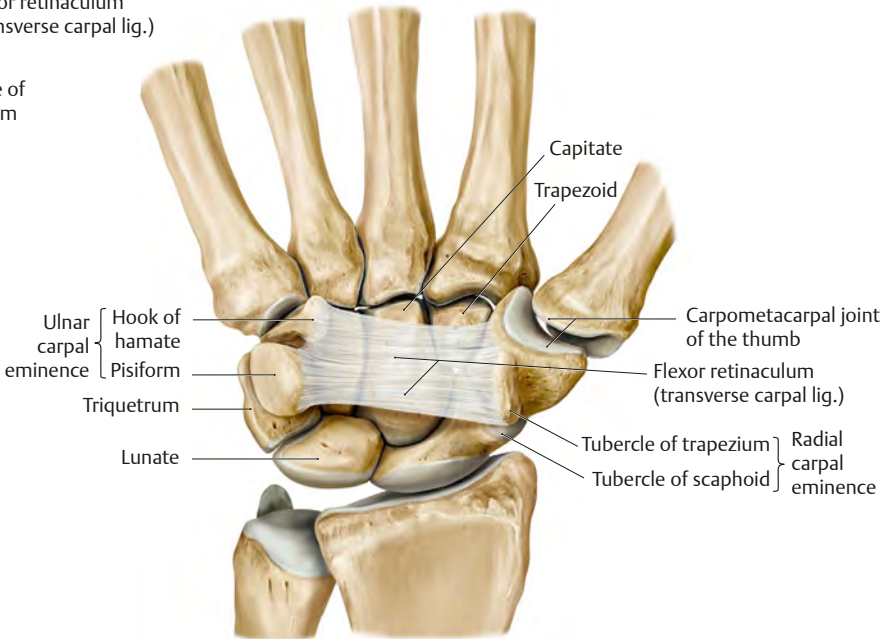


Ligaments & Compartments of the Wrist



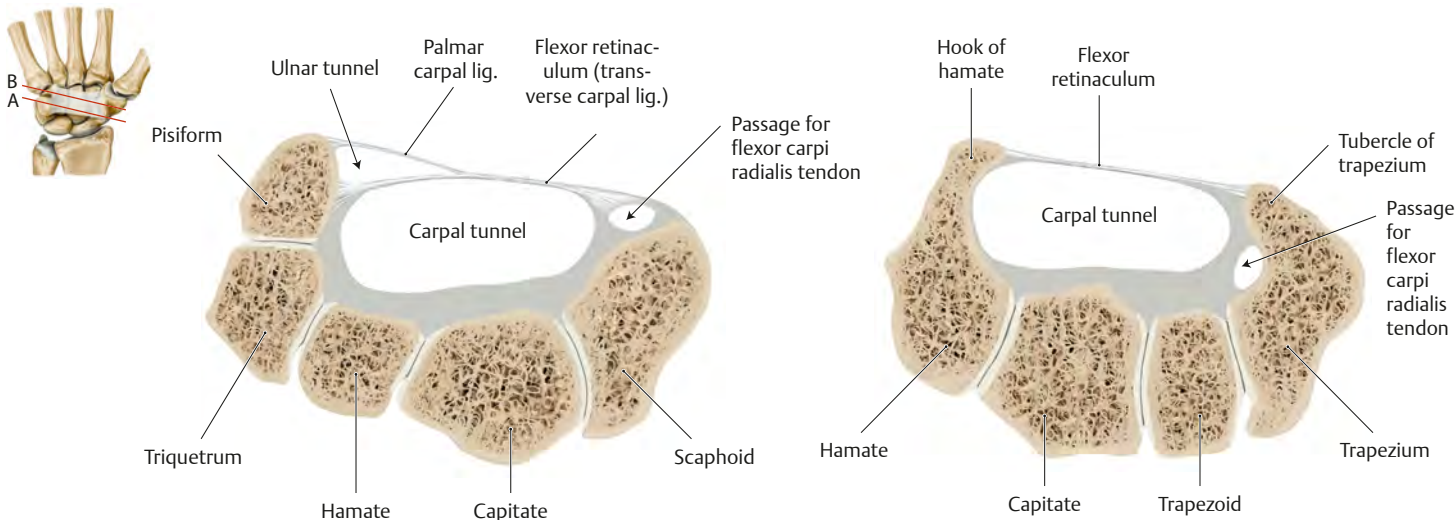
A Carpal tunnel and flexor retinaculum.

Fig. 27.9 Ligaments and bony boundaries of the carpal tunnel
Right hand, anterior (palmar) view.



B Bony boundaries of the carpal tunnel.

Fig. 27.10 Carpal tunnel
Right hand, transverse section. The contents of the carpal and ulnar tunnels are discussed on p. 391.

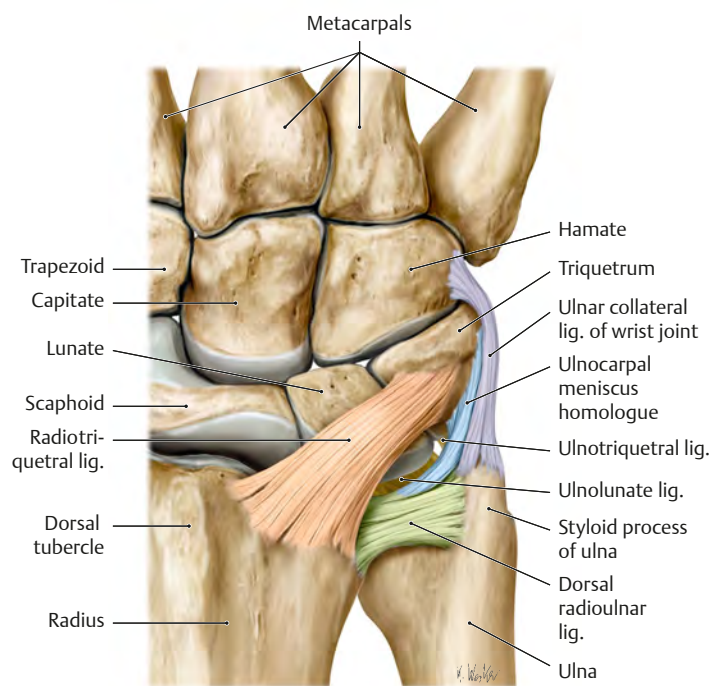
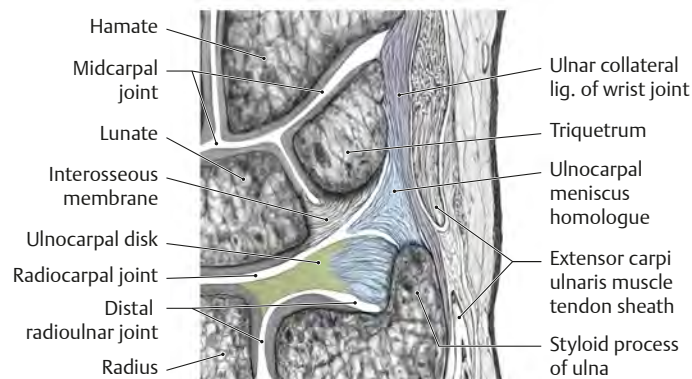
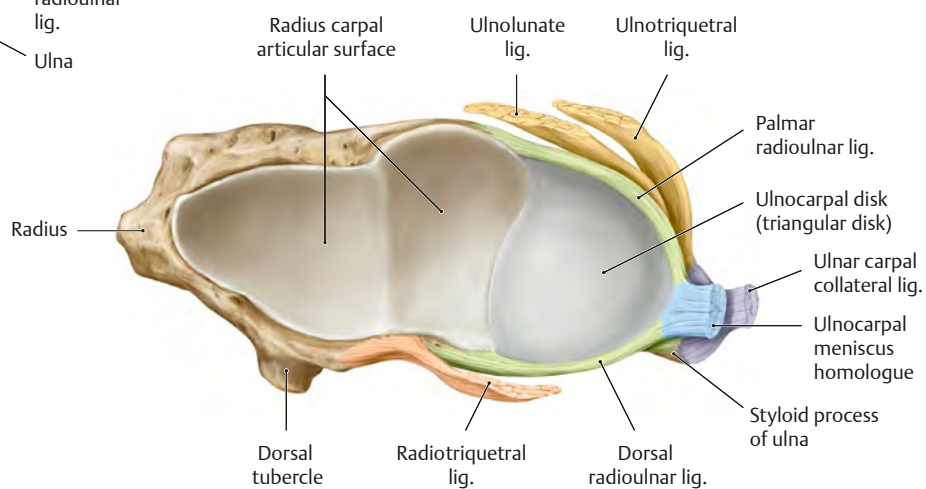


A Proximal part of the carpal tunnel.

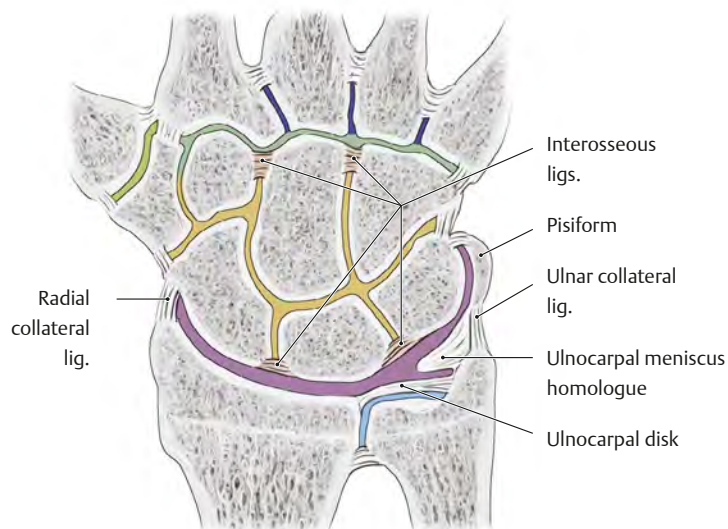
B Distal part of the carpal tunnel.

Fig. 27.11 Ulnocarpal complex

Right hand. The ulnocarpal complex (triangular fibrocartilage complex) consists of ligaments and disks that connect the distal ulna, distal radioulnar joint, and the proximal carpal row.

**A** Right wrist, posterior (dorsal) view.**B** Schematic of a section through the triangular fibrocartilage (ulnocarpal) complex.**C** Right wrist, distal view.**Fig. 27.12 Compartments of the wrist**

Right wrist, posterior view, schematic. Interosseous ligaments and the ulnocarpal disk divide the inter-articular space into compartments.



- | | |
|---|---|
| ■ Distal radioulnar joint | ■ Thumb saddle joint |
| ■ Radiocarpal joint | ■ Carpometacarpal compartment |
| ■ Medial carpal compartment | ■ Intermetacarpal joint |

Ligaments of the Fingers

Fig. 27.13 Ligaments of the fingers: Lateral view

Right middle finger. Joint capsules, ligaments, and digital tendon sheaths. The outer fibrous layer of the tendon sheaths (stratum fibrosum) is strengthened by the anular and cruciform ligaments, which

also bind the sheaths to the palmar surface of the phalanx and prevent palmar deviation of the sheaths during flexion.

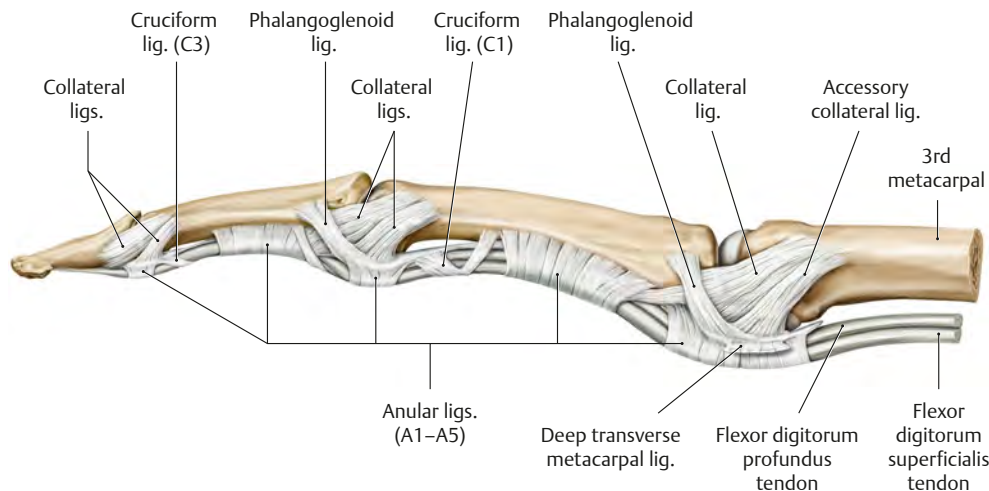
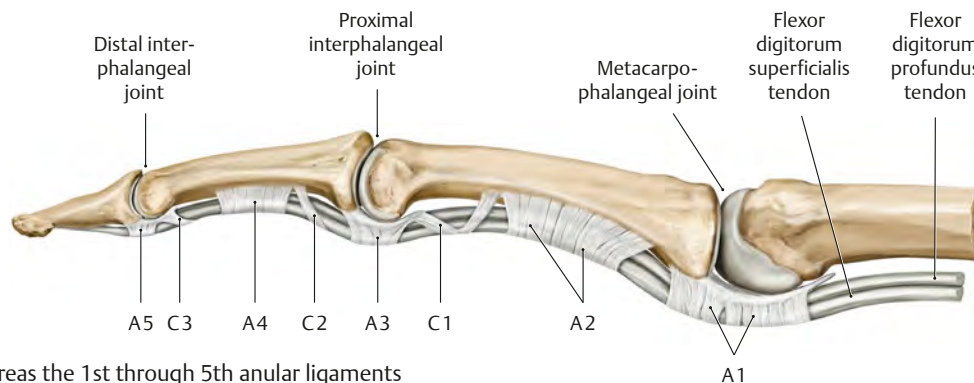


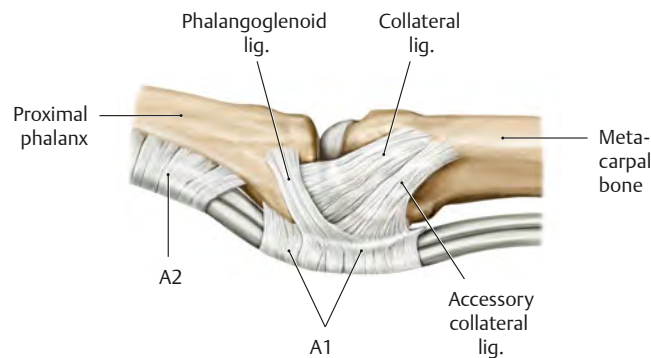
Fig. 27.14 Ligaments during extension and flexion of fingers: Lateral view



A Extension. Note: Whereas the 1st through 5th anular ligaments (A1–A5) have fixed positions, the cruciform ligaments (C1–C3) are highly variable in their course.



B Flexion.



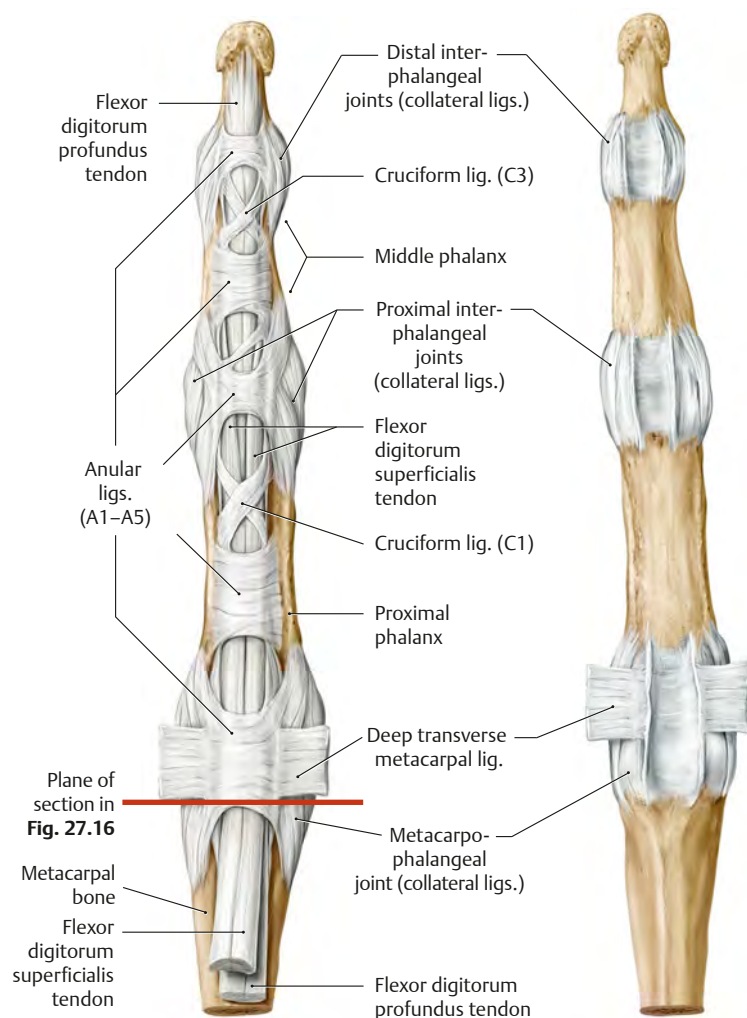
C Extension of the metacarpophalangeal joint. Note: The collateral ligament is lax.



D Flexion of the metacarpophalangeal joint. Note: The collateral ligament is taut.

Fig. 27.15 Ligaments of the fingers: Anterior (palmar) view

Right middle finger.



A Superficial ligaments.

B Deep ligaments with digital tendon sheath removed.

Fig. 27.16 Third metacarpal: Transverse section
Proximal view.

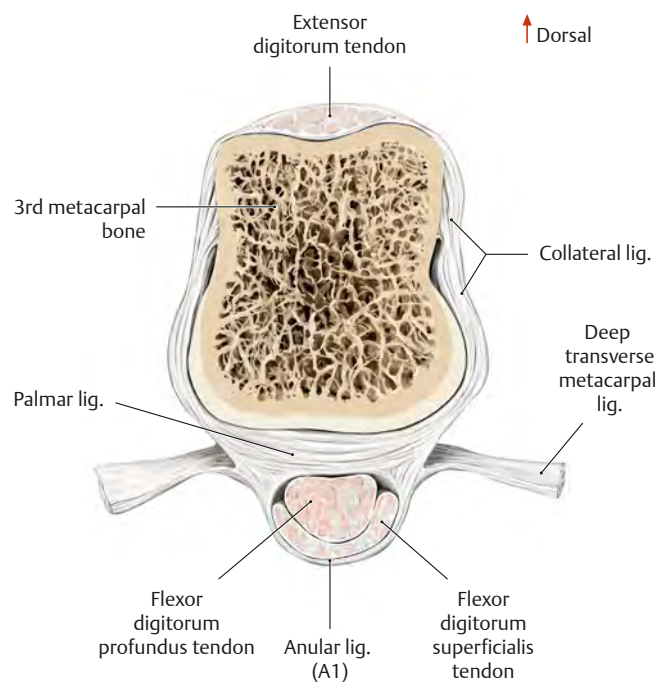
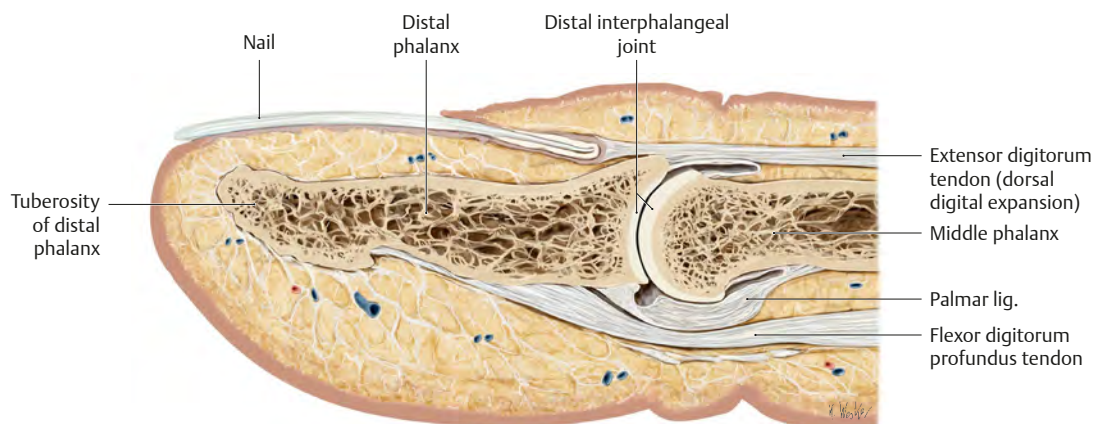


Fig. 27.17 Fingertip: Longitudinal section

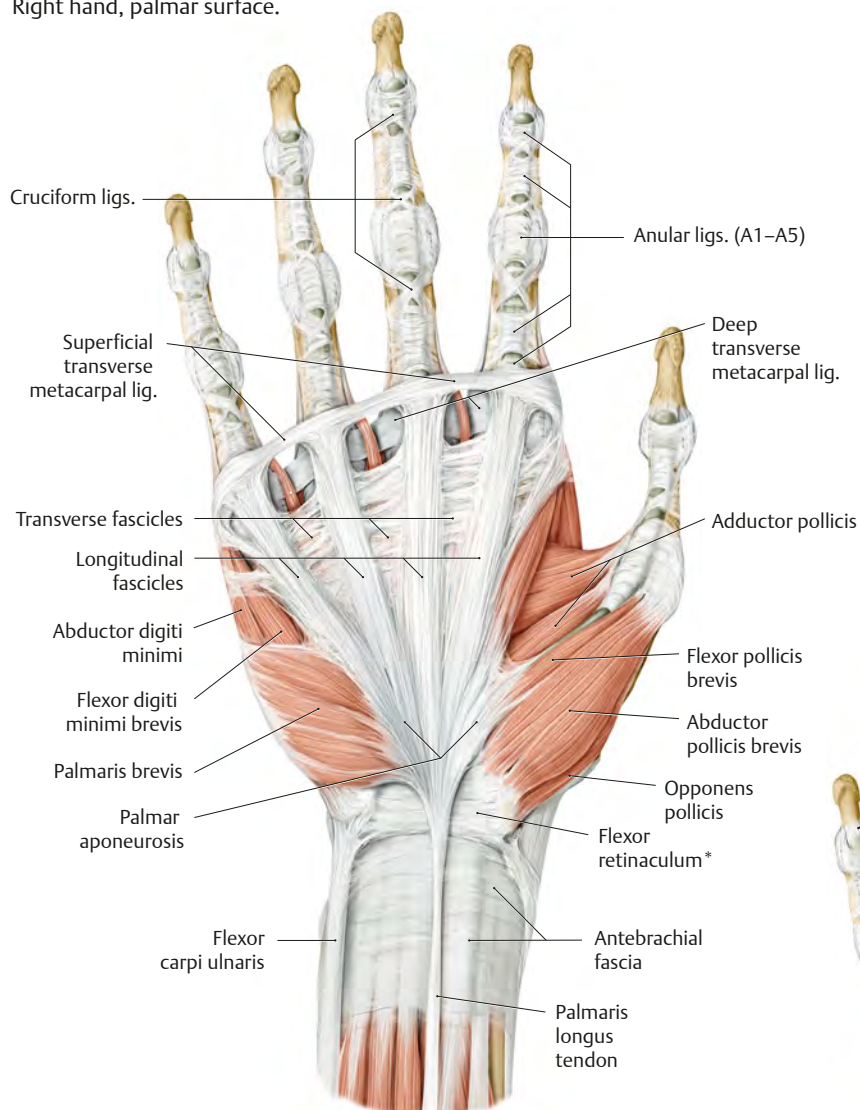
The palmar articular surfaces of the phalanges are enlarged proximally at the joints by the palmar ligament. This fibrocartilaginous plate, also known as the volar plate, forms the floor of the digital tendon sheaths.



Muscles of the Hand: Superficial & Middle Layers

Fig. 27.18 Intrinsic muscles of the hand: Superficial and middle layers

Right hand, palmar surface.



A Palmar aponeurosis.

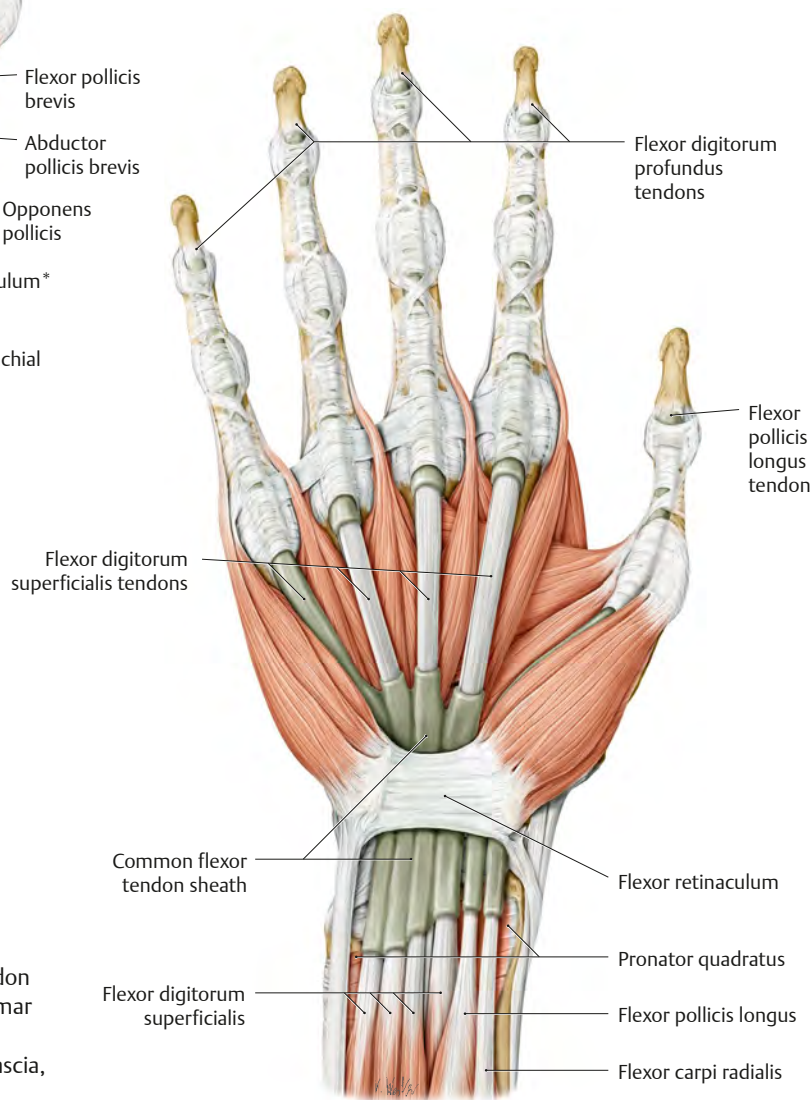
*Also known as transverse carpal ligament.



Clinical box 27.5

Dupuytren's contracture

Gradual atrophy of the palmar aponeurosis leads to progressive shortening of the palmar fascia, chiefly affecting the 4th and 5th digits. Over a period of years, the contracture may become so severe that the fingers assume a flexed position (with fingertips touching the palms), severely compromising the grasping ability of the hand. The causes of Dupuytren's contracture are poorly understood, but it is a relatively common condition, most prevalent in men over 40 and associated with chronic liver disease (i.e., cirrhosis). Treatment generally consists of complete surgical removal of the palmar aponeurosis.



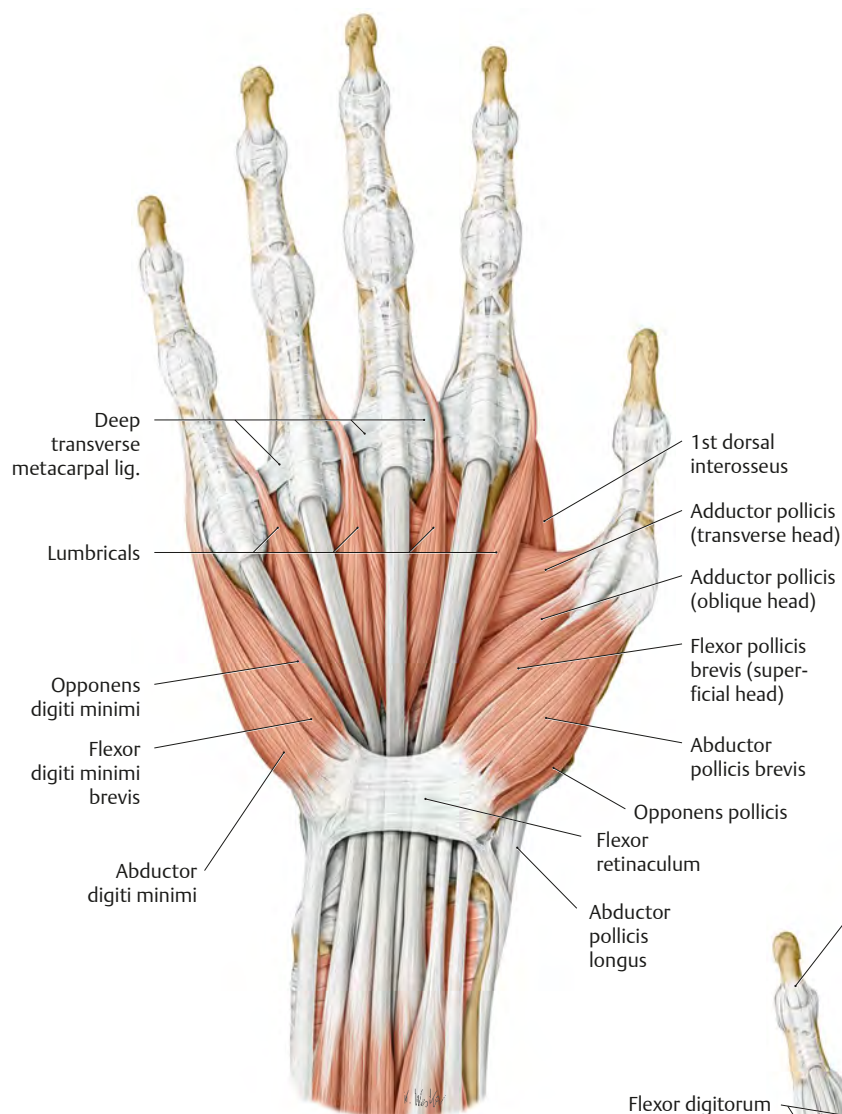
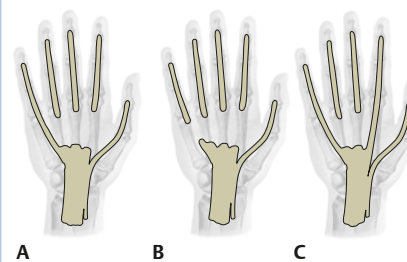
B Carpal and digital tendon sheaths. *Removed:* Palmar aponeurosis, palmaris longus, antebrachial fascia, and palmaris brevis.



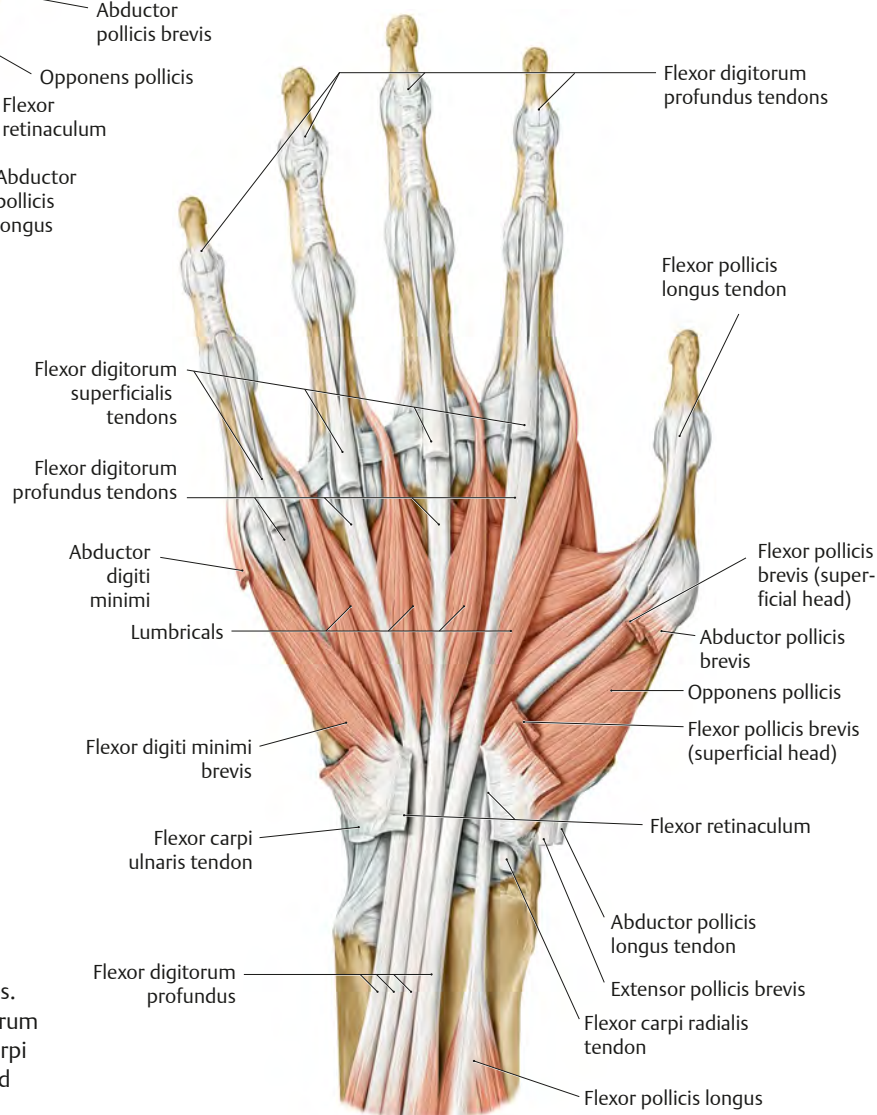
Clinical box 27.6

Tendon sheath communication

The digital tendon sheath of the thumb is continuous with the carpal tendon sheath of the flexor pollicis longus. The remaining fingers show variable communication with the carpal tendon sheaths (**A** is the most common variation). Infections within the tendon sheaths from puncture wounds of the fingers can track proximally to communicating spaces of the hand.



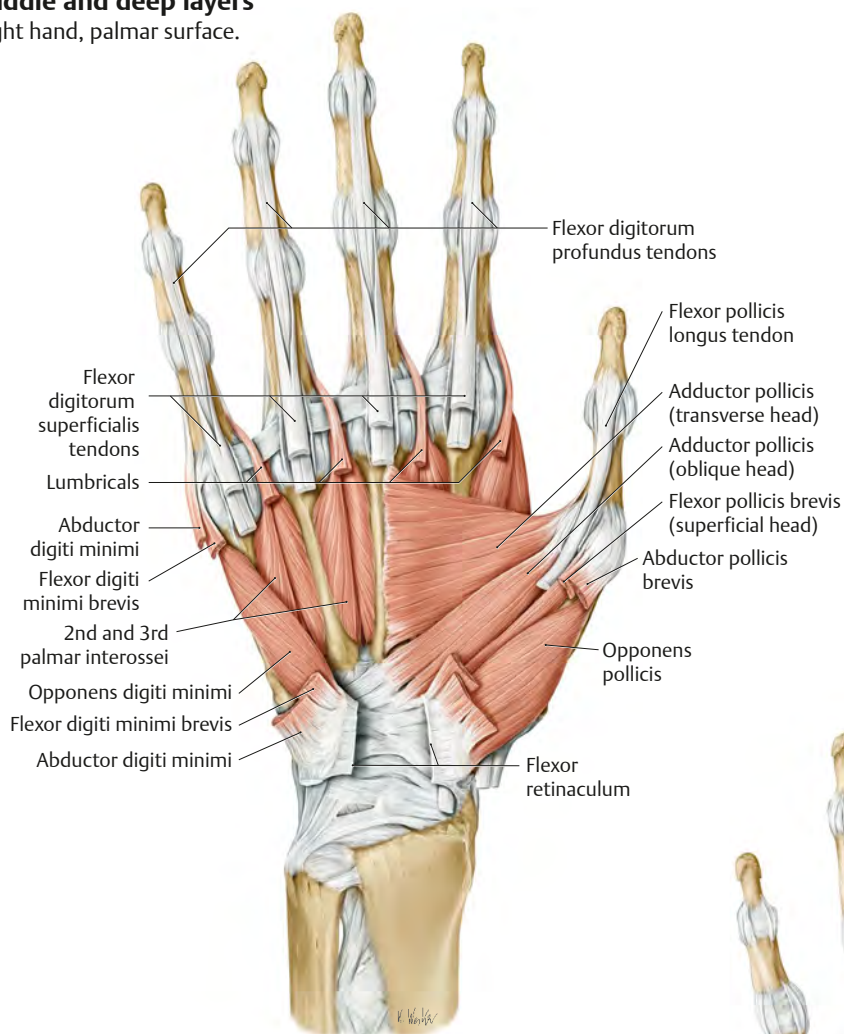
C Superficial layer of muscles.
Removed: Tendon sheaths.



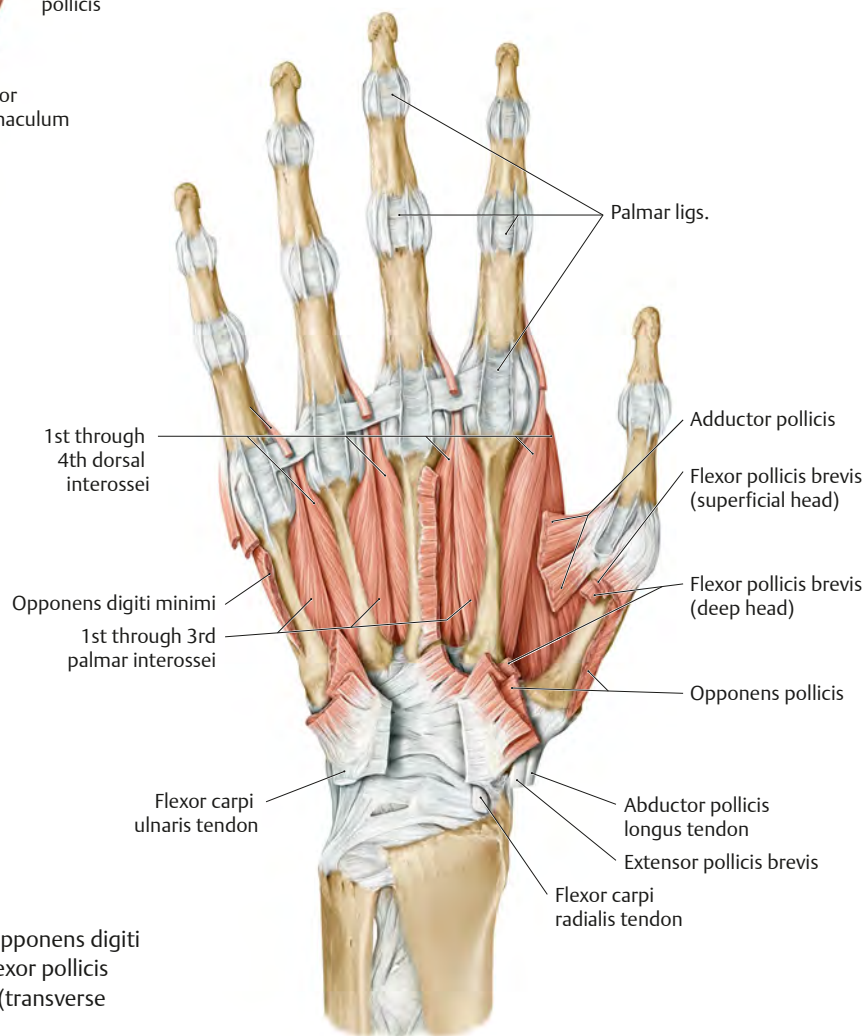
D Middle layer of muscles.
Removed: Flexor digitorum superficialis, flexors carpi radialis and ulnaris, and pronator quadratus.

Muscles of the Hand: Middle & Deep Layers

Fig. 27.19 Intrinsic muscles of the hand:
Middle and deep layers
Right hand, palmar surface.



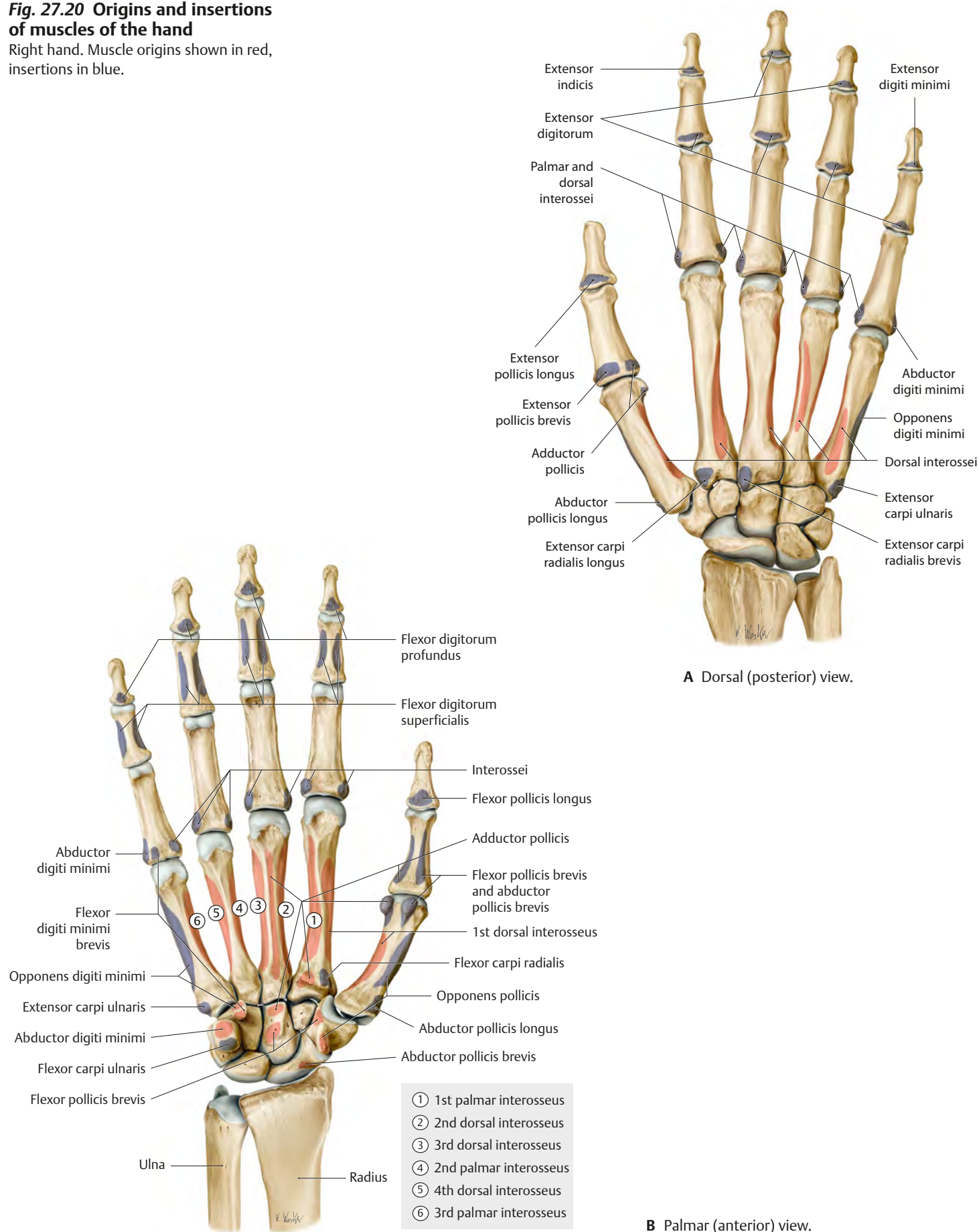
A Middle layer of muscles. *Cut:* Flexor digitorum profundus, lumbricals, flexor pollicis longus, and flexor digiti minimi brevis.



B Deep layer of muscles. *Cut:* Opponens digiti minimi, opponens pollicis, flexor pollicis brevis, and adductor pollicis (transverse and oblique heads).

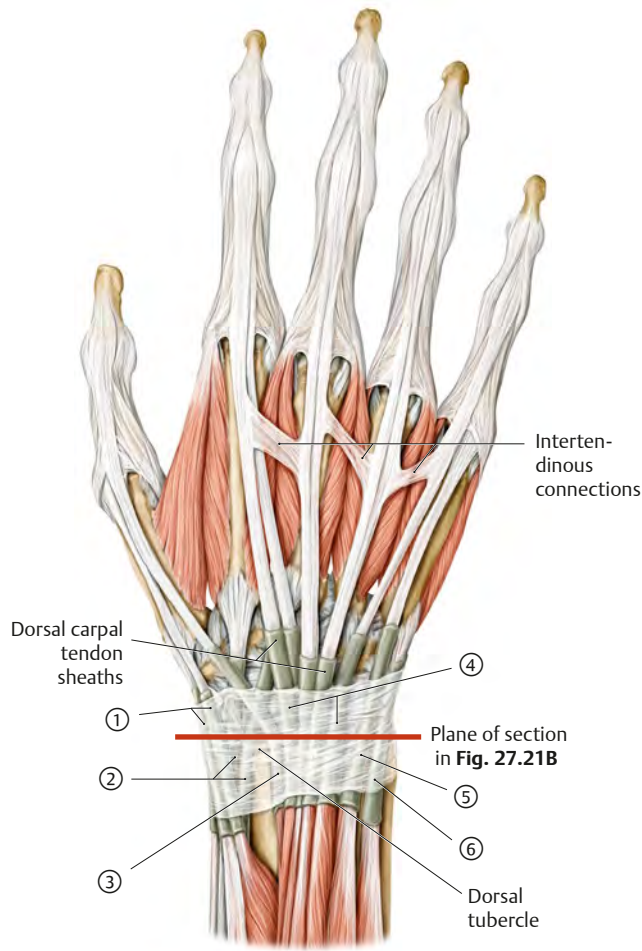
Fig. 27.20 Origins and insertions of muscles of the hand

Right hand. Muscle origins shown in red, insertions in blue.



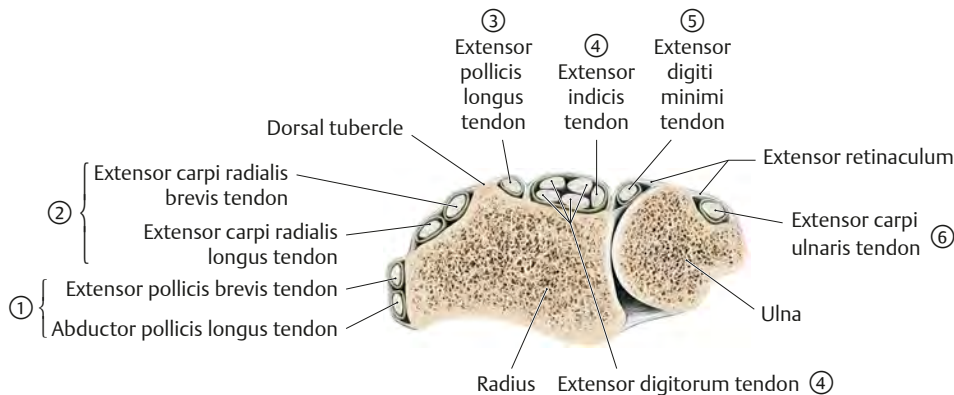
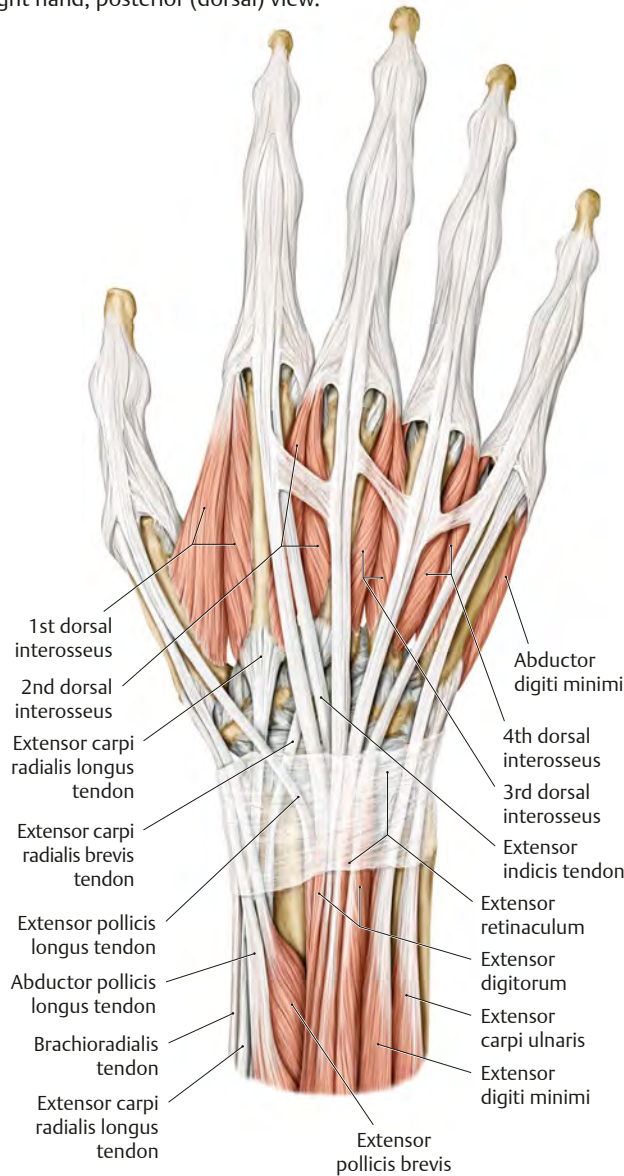
Dorsum of the Hand

Fig. 27.21 Extensor retinaculum and dorsal carpal tendon sheaths



A Right hand, posterior (dorsal) view.

Fig. 27.22 Muscles and tendons of the dorsum
Right hand, posterior (dorsal) view.

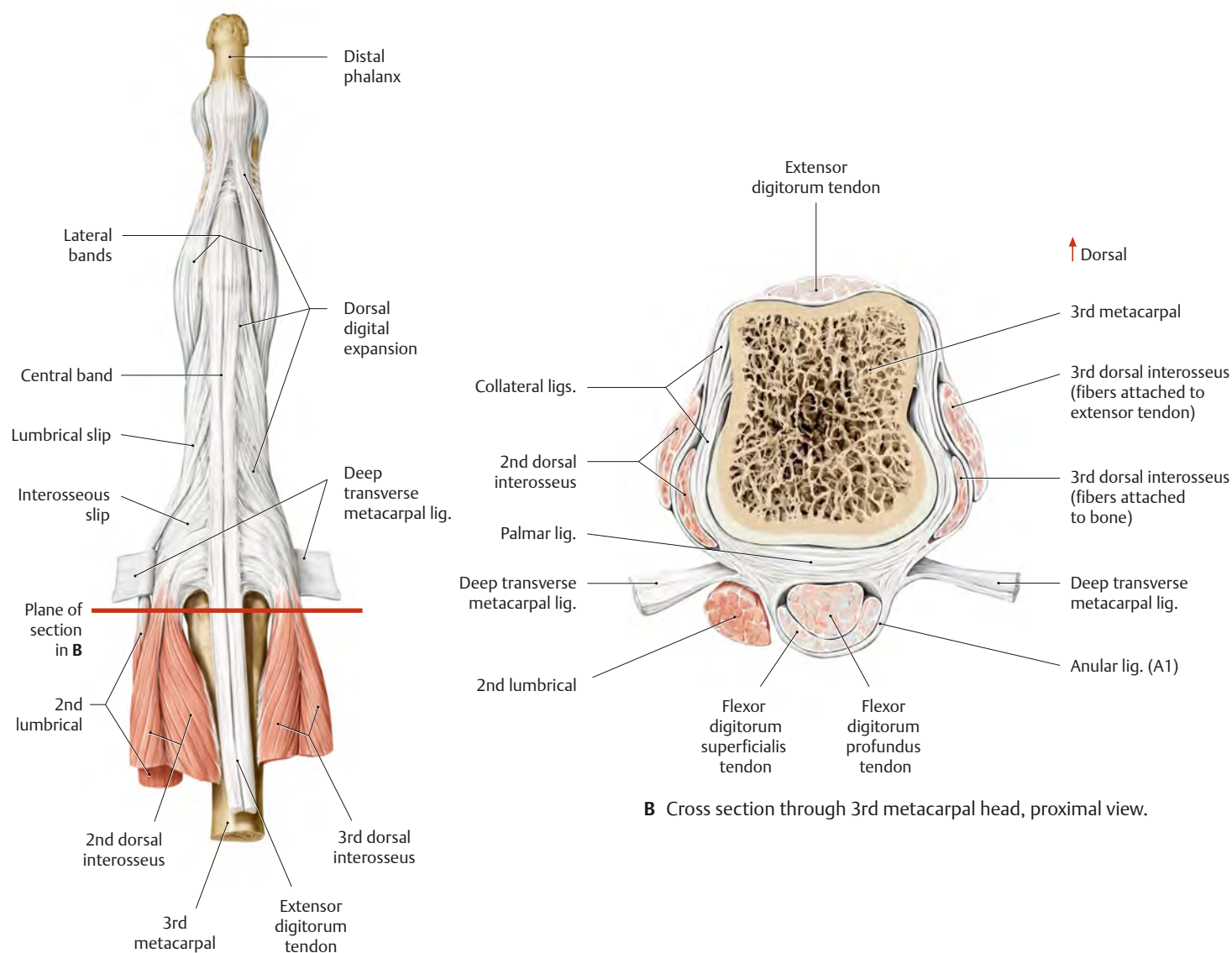
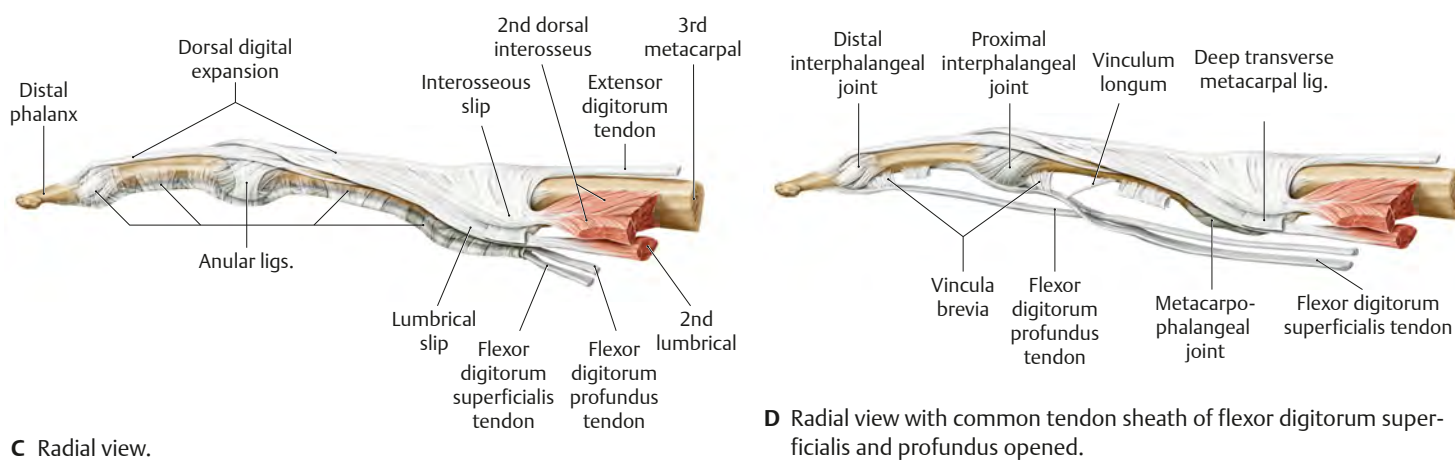


B Posterior (dorsal) compartments, proximal view of section in Fig. 27.21A.

Table 27.2		Dorsal compartments for extensor tendons
①	Abductor pollicis longus	
	Extensor pollicis brevis	
②	Extensor carpi radialis longus	
	Extensor carpi radialis brevis	
③	Extensor pollicis longus	
④	Extensor digitorum	
	Extensor indicis	
⑤	Extensor digiti minimi	
⑥	Extensor carpi ulnaris	

Fig. 27.23 Dorsal digital expansion

Right hand, middle finger. The dorsal digital expansion permits the long digital flexors and the short muscles of the hand to act on all three finger joints.

**A** Posterior view.**B** Cross section through 3rd metacarpal head, proximal view.**C** Radial view.**D** Radial view with common tendon sheath of flexor digitorum superficialis and profundus opened.

Muscle Facts (I)

The intrinsic muscles of the hand are divided into three groups: the thenar, hypothenar, and metacarpal muscles (see p. 362). The thenar

muscles are responsible for movement of the thumb, while the hypothenar muscles move the 5th digit.

Table 27.3	Thenar muscles						
Muscle		Origin	Insertion	Innervation		Action	
① Adductor pollicis		Transverse head: 3rd metacarpal (palmar surface)	Thumb (base of proximal phalanx) via the ulnar sesamoid	Via the ulnar sesamoid	Ulnar n. (C8, T1)	C8, T1	CMC joint of thumb: adduction MCP joint of thumb: flexion
		Oblique head: capitate bone, 2nd and 3rd metacarpals (bases)					
② Abductor pollicis brevis		Scaphoid bone and trapezium, flexor retinaculum	Thumb (base of proximal phalanx) via the radial sesamoid	Via the radial sesamoid	Median n. (C8, T1)		CMC joint of thumb: abduction
③ Flexor pollicis brevis		Superficial head: flexor retinaculum			Superficial head: median n. (C8, T1)		CMC joint of thumb: flexion
		Deep head: capitate bone, trapezium	Deep head: ulnar n. (C8, T1)				
④ Opponens pollicis		Trapezium	1st metacarpal (radial border)		Median n. (C8, T1)	CMC joint of thumb: opposition	
CMC, carpometacarpal; MCP, metacarpophalangeal.							

Fig. 27.24 Thenar and hypothenar muscles
Right hand, palmar (anterior) view, schematic.

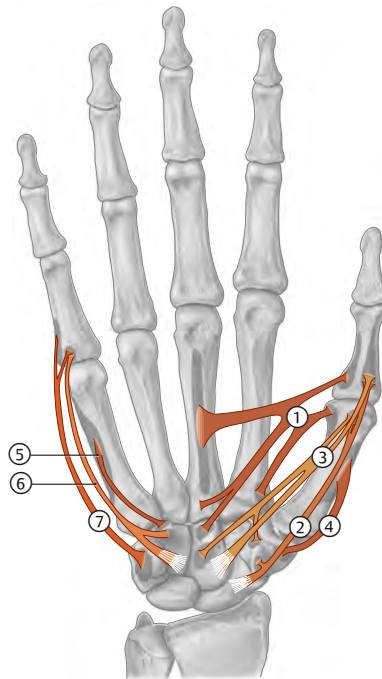
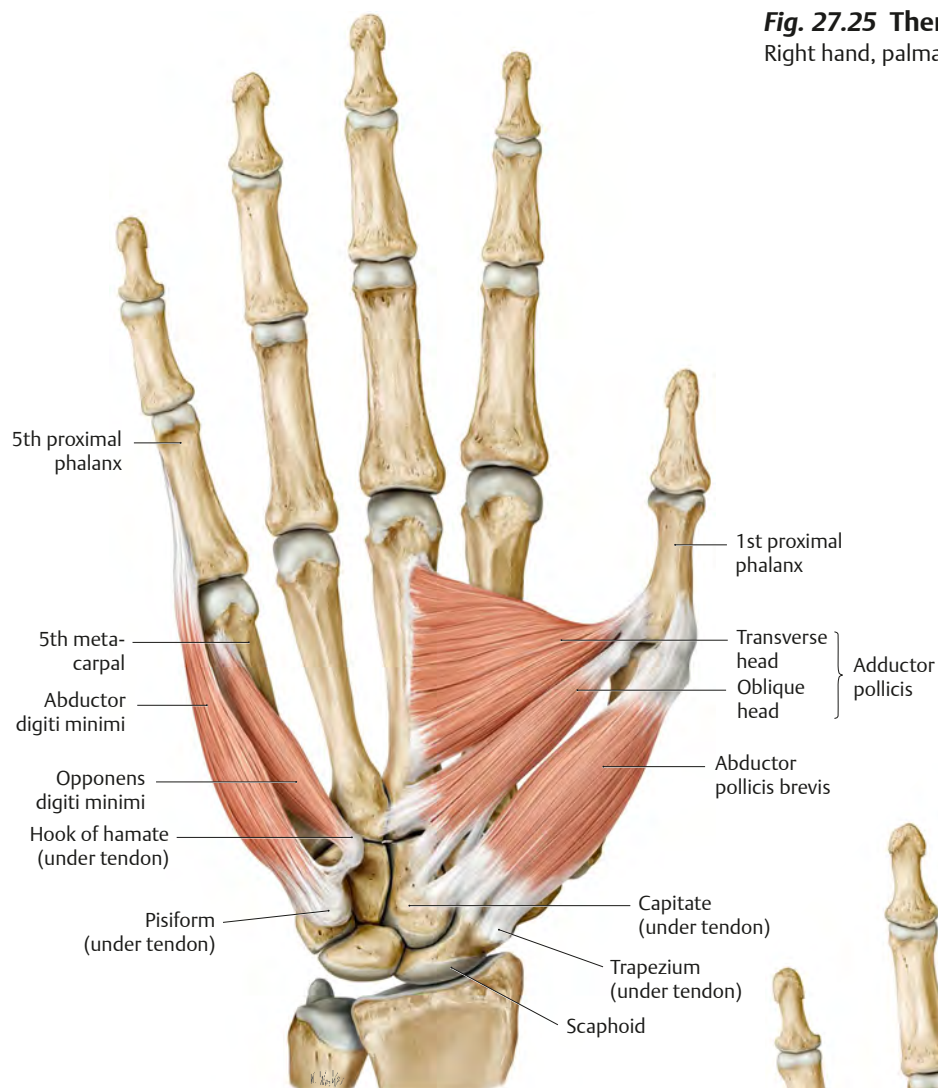
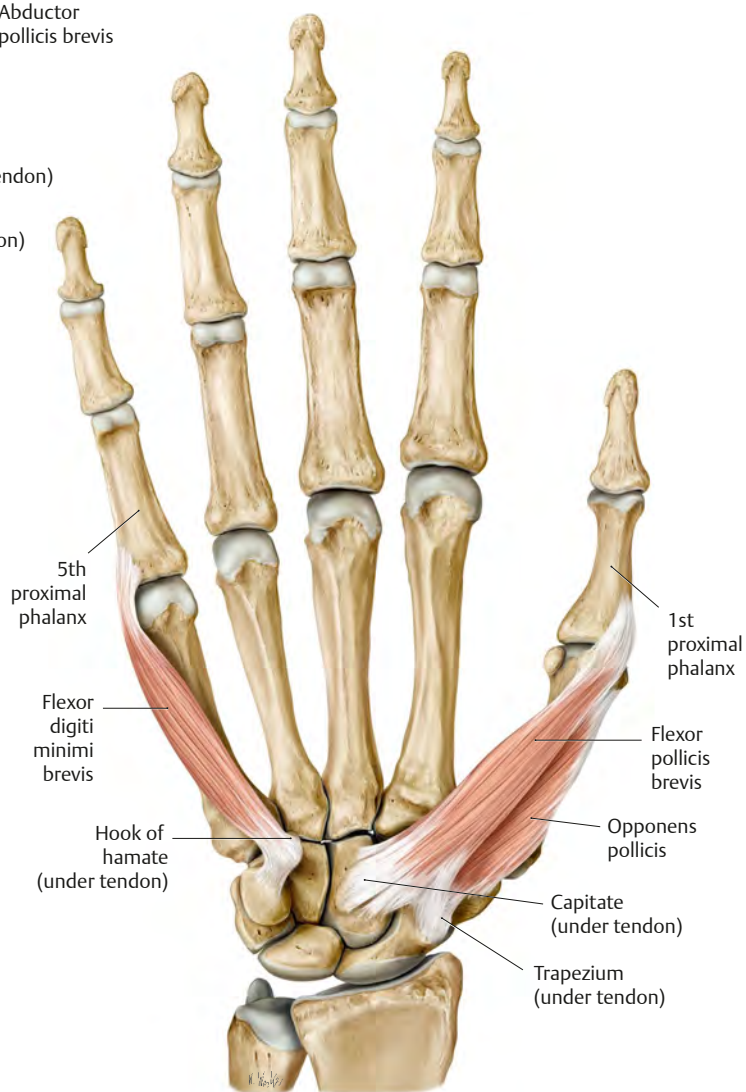


Table 27.4 Hypothenar muscles				
Muscle	Origin	Insertion	Innervation	Action
⑤ Opponens digiti minimi	Hook of hamate, flexor retinaculum	5th metacarpal (ulnar border)	Ulnar n. (C8, T1)	Draws metacarpal in palmar direction (opposition)
⑥ Flexor digiti minimi brevis		5th proximal phalanx (base)		MCP joint of little finger: flexion
⑦ Abductor digiti minimi	Pisiform bone	5th proximal phalanx (ulnar base) and dorsal digital expansion of 5th digit		MCP joint of little finger: flexion and abduction of little finger PIP and DIP joints of little finger: extension
Palmaris brevis	Palmar aponeurosis (ulnar border)	Skin of hypothenar eminence		Tightens the palmar aponeurosis (protective function)
DIP, distal interphalangeal; MCP, metacarpophalangeal; PIP, proximal interphalangeal.				

Fig. 27.25 Thenar and hypothenar muscles
Right hand, palmar (anterior) view.



A Removed: Flexor pollicis brevis, opponens pollicis, and flexor digiti minimi brevis.



B Removed: Adductor pollicis, abductor pollicis brevis, abductor digiti minimi, and opponens digiti minimi.

Muscle Facts (II)

The metacarpal muscles of the hand consist of the lumbricals and interossei. They are responsible for the movement of the digits (with the hypothenars, which act on the 5th digit).

Fig. 27.26 Metacarpal muscles of the hand
Right hand, palmar view, schematic.

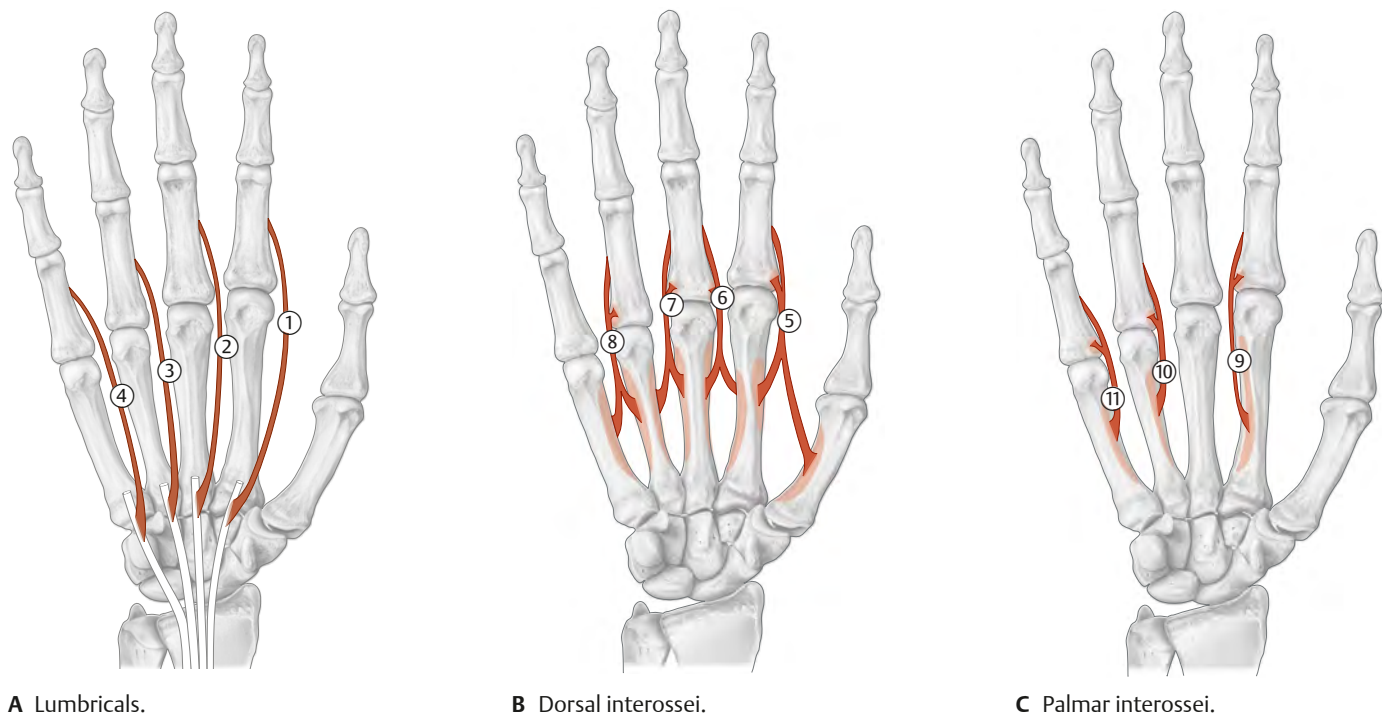
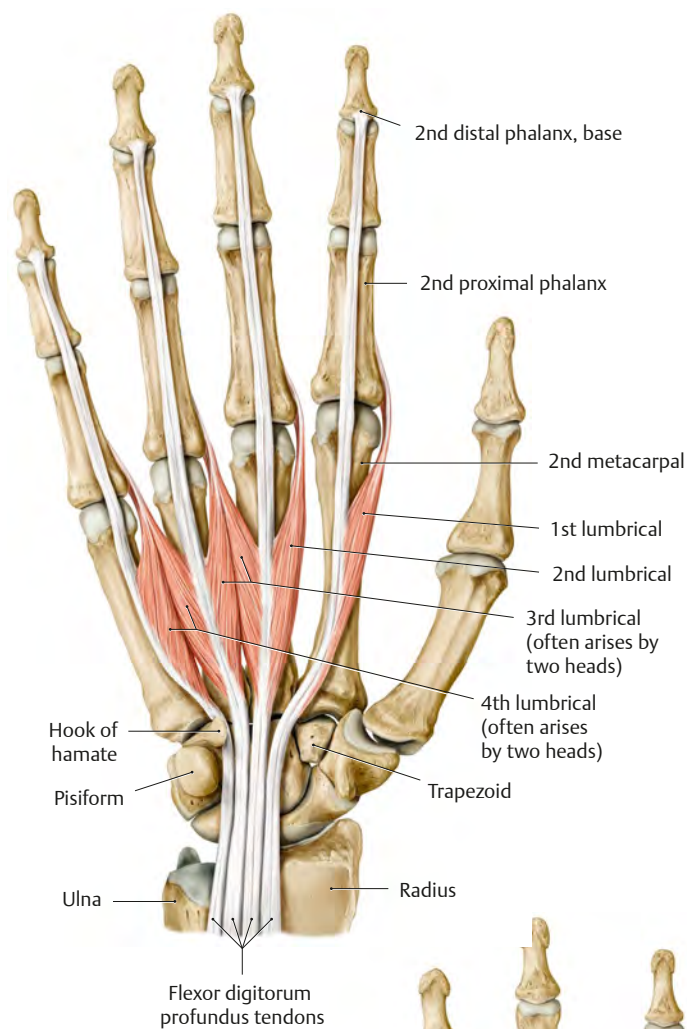
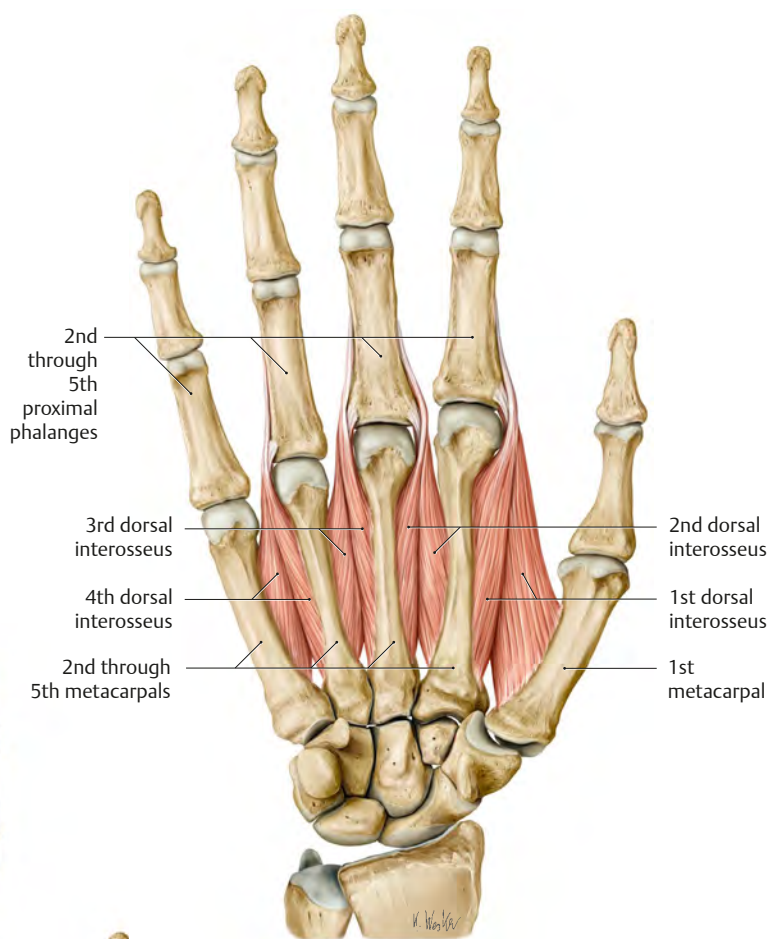
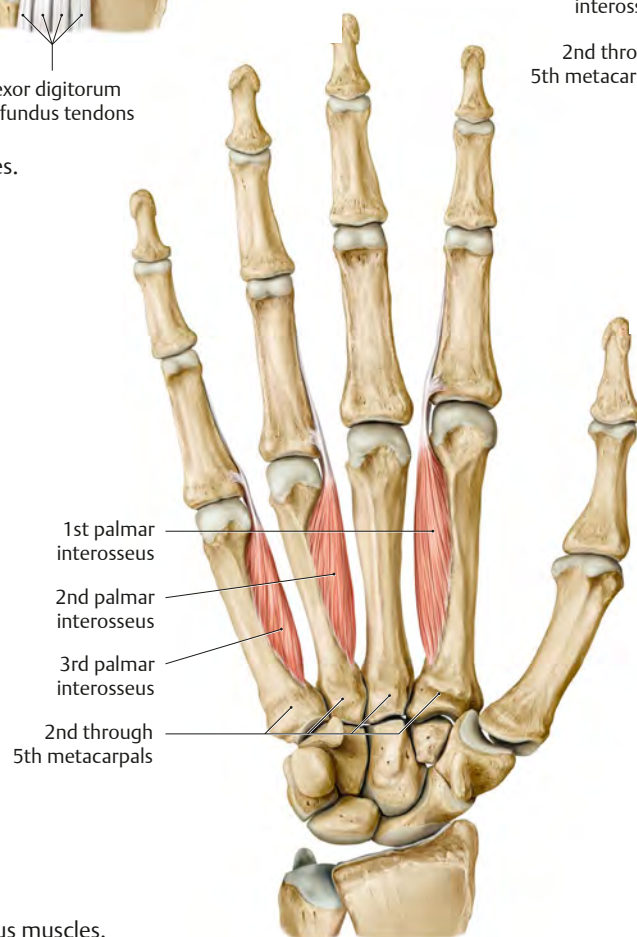


Table 27.5		Metacarpal muscles			
Muscle group	Muscle	Origin	Insertion	Innervation	Action
Lumbricals	① 1st	Tendons of flexor digitorum profundus (radial sides)	2nd digit (dde)	Median n. (C8, T1)	2nd to 5th digits: • MCP joints: flexion • Proximal and distal IP joints: extension
	② 2nd		3rd digit (dde)		
	③ 3rd	Tendons of flexor digitorum profundus (bipennate from medial and lateral sides)	4th digit (dde)		
	④ 4th		5th digit (dde)		
Dorsal interossei	⑤ 1st	1st and 2nd metacarpals (adjacent sides, two heads)	2nd digit (dde) 2nd proximal phalanx (radial side)	Ulnar n. (C8, T1)	2nd to 4th digits: • MCP joints: flexion • Proximal and distal IP joints: extension and abduction from 3rd digit
	⑥ 2nd	2nd and 3rd metacarpals (adjacent sides, two heads)	3rd digit (dde) 3rd proximal phalanx (radial side)		
	⑦ 3rd	3rd and 4th metacarpals (adjacent sides, two heads)	3rd digit (dde) 3rd proximal phalanx (ulnar side)		
	⑧ 4th	4th and 5th metacarpals (adjacent sides, two heads)	4th digit (dde) 4th proximal phalanx (ulnar side)		
Palmar interossei	⑨ 1st	2nd metacarpal (ulnar side)	2nd digit (dde) 2nd proximal phalanx (base)		2nd, 4th, and 5th digits: • MCP joints: flexion • Proximal and distal IP joints: extension and adduction toward 3rd digit
	⑩ 2nd	4th metacarpal (radial side)	4th digit (dde) 4th proximal phalanx (base)		
	⑪ 3rd	5th metacarpal (radial side)	5th digit (dde) 5th proximal phalanx (base)		
dde, dorsal digital expansion; IP, interphalangeal; MCP, metacarpophalangeal.					

Fig. 27.27 Metacarpal muscles

Right hand, palmar (anterior) view.

**A** Lumbrical muscles.**B** Dorsal interosseus muscles.**C** Palmar interosseus muscles.

28 Neurovasculature

Arteries of the Upper Limb

Fig. 28.1 Arteries of the upper limb
Right limb with the forearm supinated, anterior view.

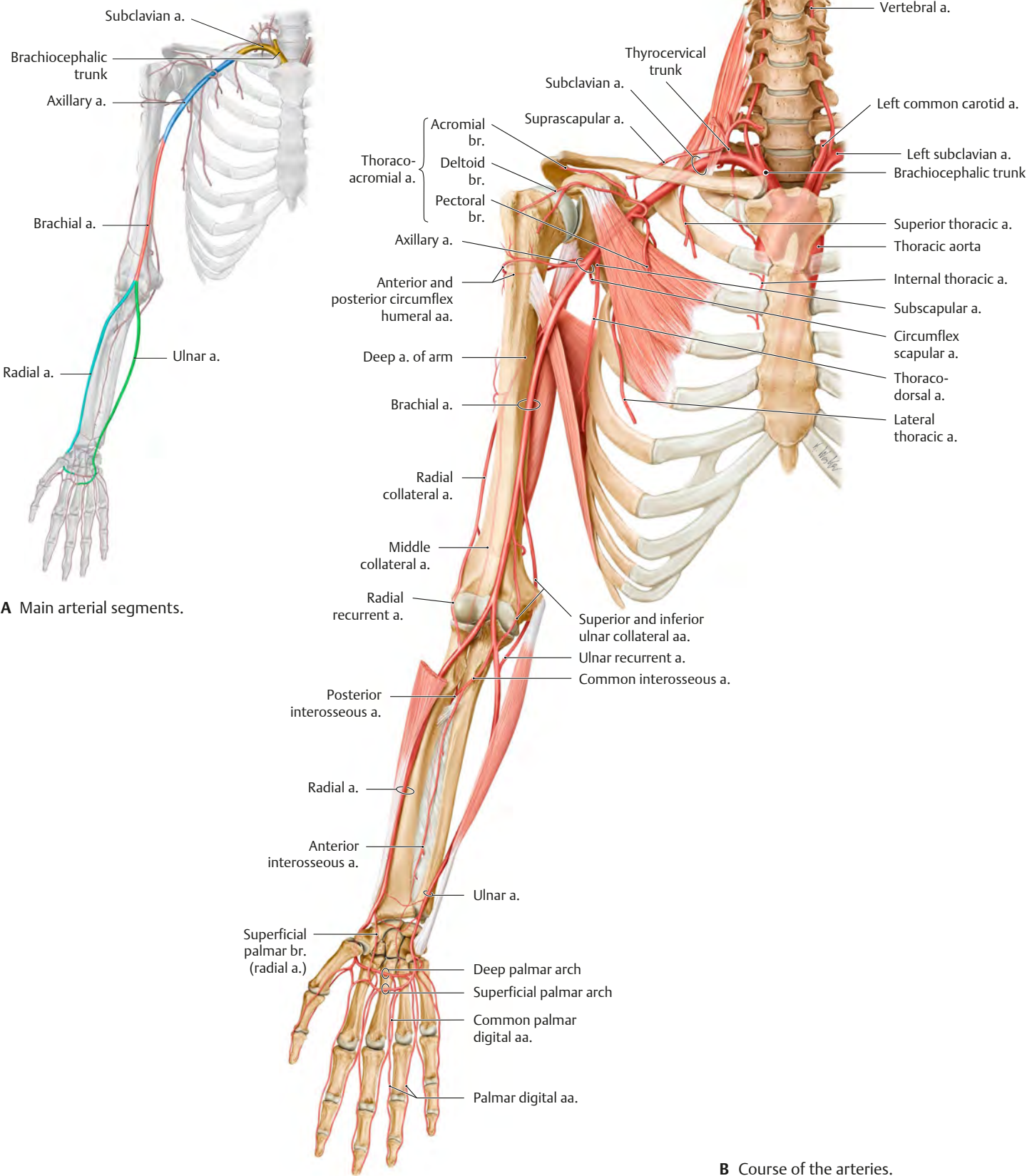
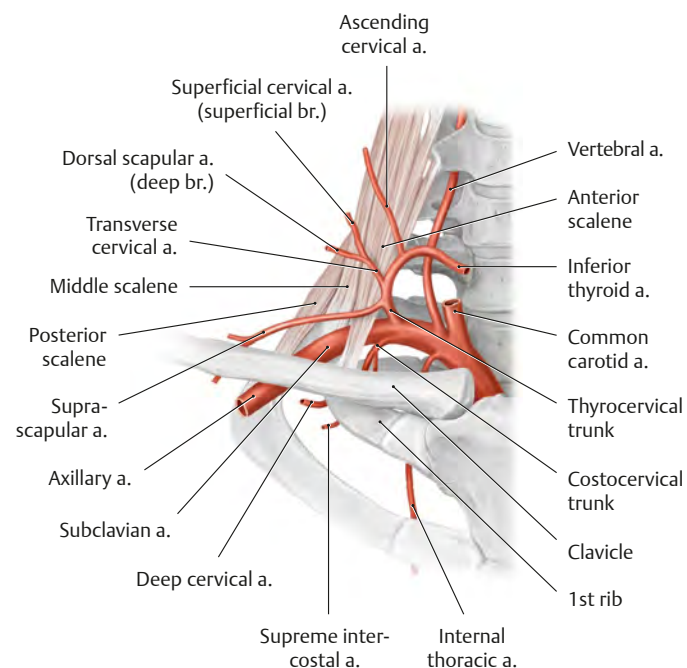
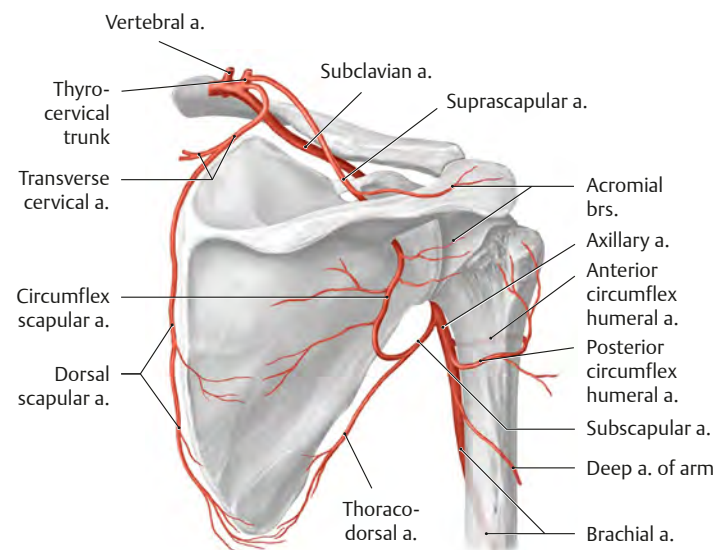


Fig. 28.2 Branches of the subclavian artery

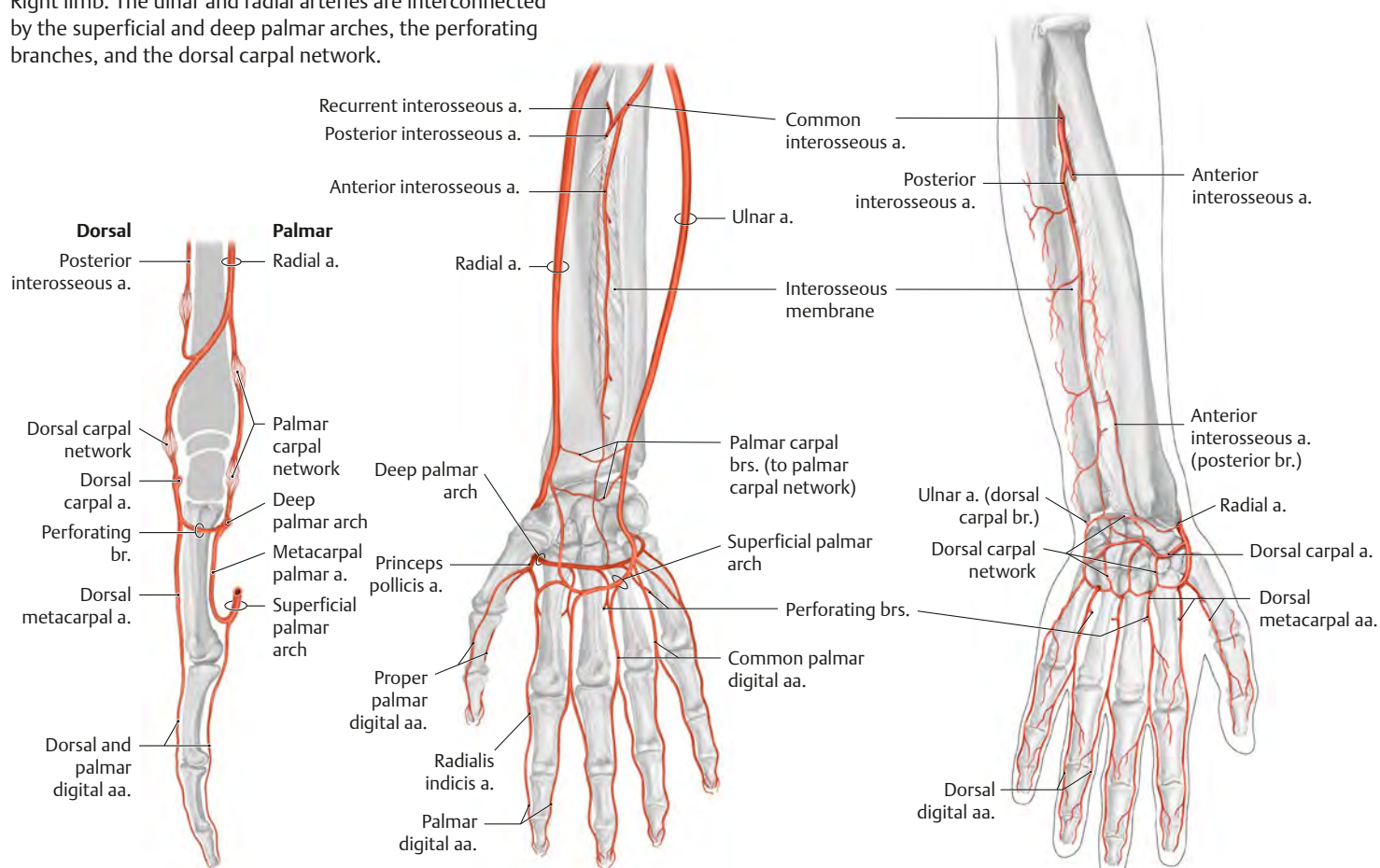
Right side, anterior view.

**Fig. 28.3 Scapular arcade**

Right side, posterior view.

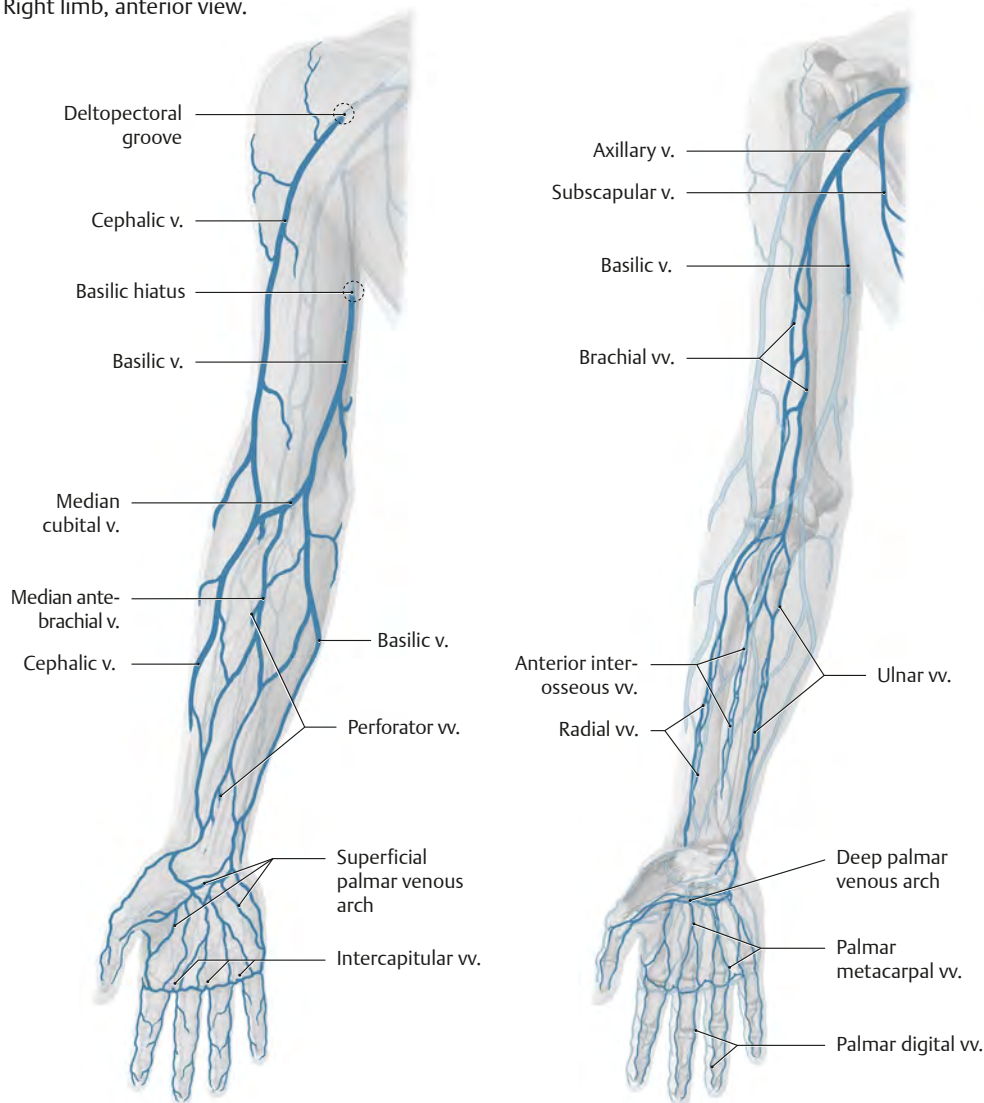
**Fig. 28.4 Arteries of the forearm and hand**

Right limb. The ulnar and radial arteries are interconnected by the superficial and deep palmar arches, the perforating branches, and the dorsal carpal network.

**A** Right middle finger, lateral view.**B** Anterior (palmar) view.**C** Posterior (dorsal) view.

Veins & Lymphatics of the Upper Limb

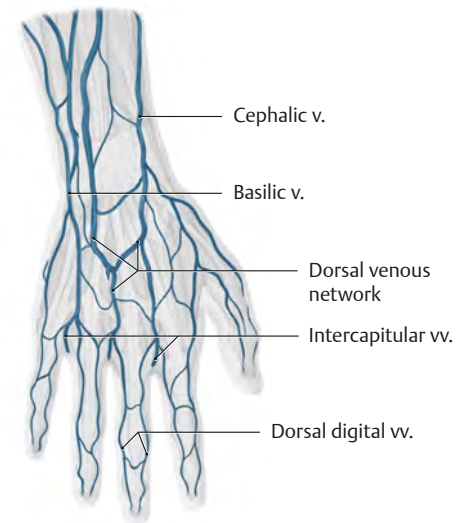
Fig. 28.5 Veins of the upper limb
Right limb, anterior view.



A Superficial veins.

B Deep veins.

Fig. 28.6 Veins of the dorsum
Right hand, posterior view.



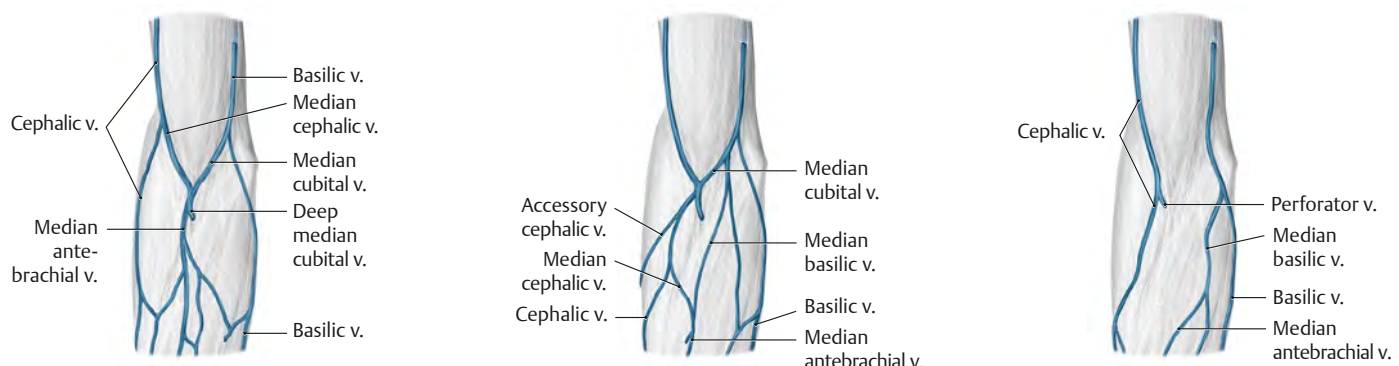
Clinical box 28.1

Venipuncture

The veins of the cubital fossa are frequently used when drawing blood. In preparation, a tourniquet is applied above the cubital fossa. This allows arterial blood to flow, but blocks the return of venous blood. The resulting swelling makes the veins more visible and palpable.

Fig. 28.7 Cubital fossa

Right limb, anterior view. The subcutaneous veins of the cubital fossa have a highly variable course.



A M-shaped.

B Accessory cephalic vein.

C Absent median cubital vein.

Lymph from the upper limb and breast drains to the axillary lymph nodes. The superficial lymphatics of the upper limb lie in the subcutaneous

tissue, while the deep lymphatics accompany the arteries and deep veins. Numerous anastomoses exist between the two systems.

Fig. 28.8 Lymph vessels of the upper limb

Right limb.

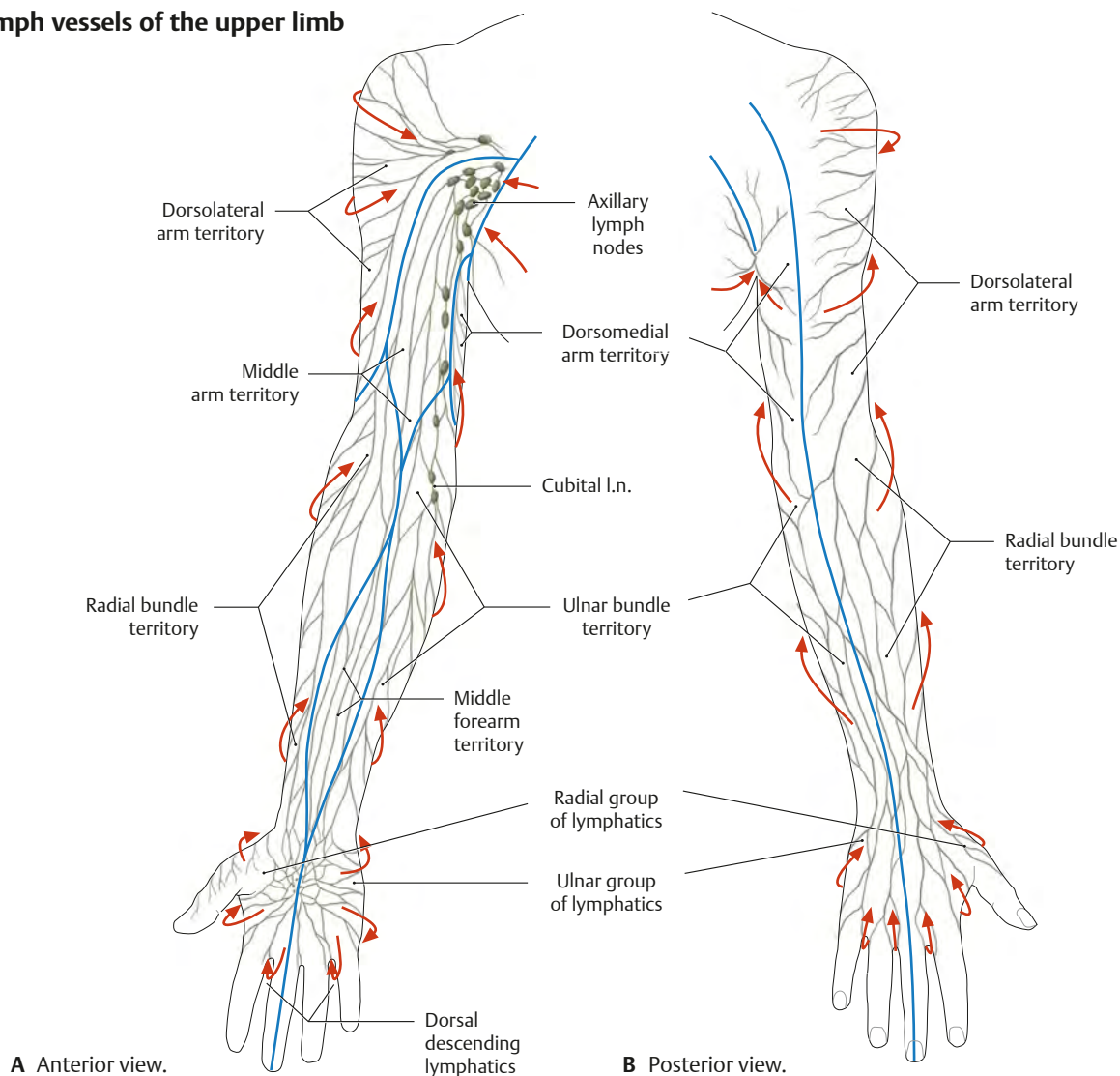


Fig. 28.9 Lymphatic drainage of the hand

Right hand, radial view. Most of the hand drains to the axillary nodes via cubital nodes. However, the thumb, index finger, and dorsum of the hand drain directly.

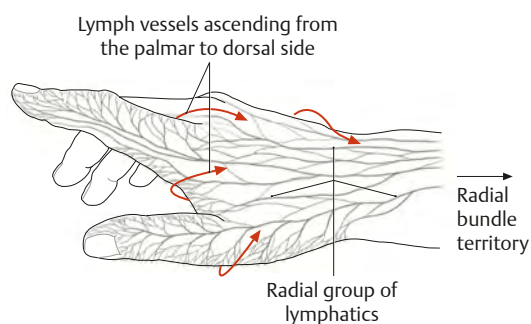
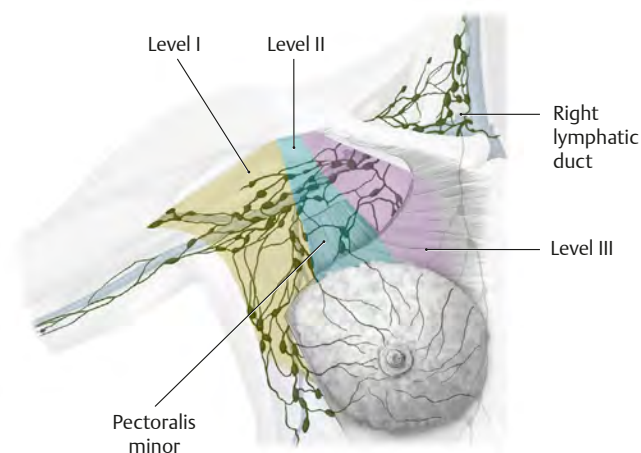


Fig. 28.10 Axillary lymph nodes

Right side, anterior view. For surgical purposes, the axillary lymph nodes are divided into three levels with respect to their relationship with the pectoralis minor: lateral (level I), posterior (level II), or medial (level III). They have major clinical importance in breast cancer (see p. 76).



Nerves of the Upper Limb: Brachial Plexus

Almost all muscles in the upper limb are innervated by the brachial plexus, which arises from spinal cord segments C5 to T1. The anterior rami of the spinal nerves give off direct branches (supraclavicular part of the brachial plexus) and merge to form three trunks, six divisions

(three anterior and three posterior), and three cords. The infraclavicular part of the brachial plexus consists of short branches that arise directly from the cords and long (terminal) branches that traverse the limb.

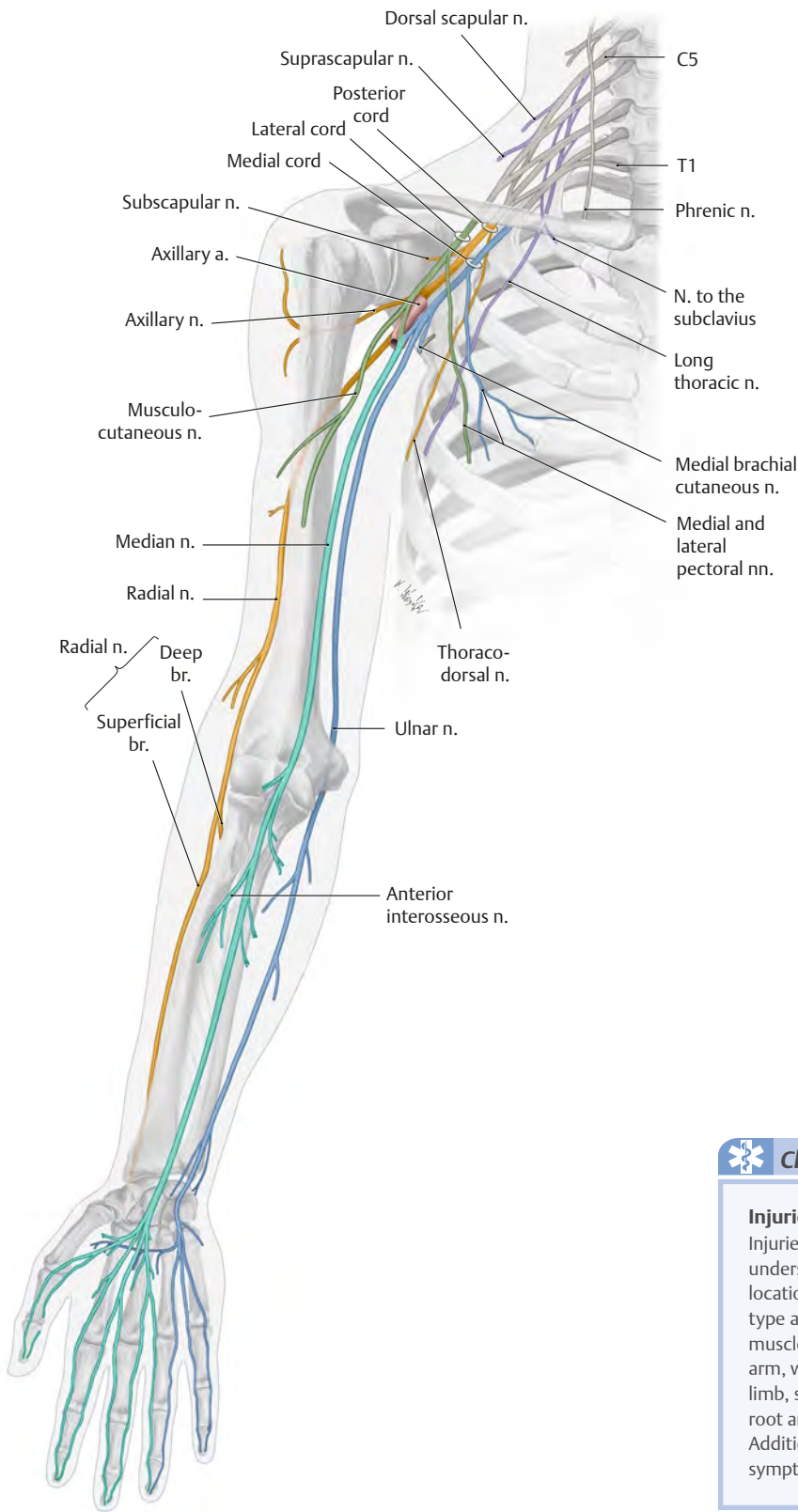


Table 28.1 Nerves of the brachial plexus

Supraclavicular part				
Direct branches from the anterior rami or plexus trunks				
	Dorsal scapular n.			C4–C5
	Suprascapular n.			C5, C6
	N. to the subclavius			C5–C6
	Long thoracic n.			C5–C7
Infraclavicular part				
Short and long branches from the plexus cords				
	Lateral cord	Lateral pectoral n.		C5–C7
		Musculocutaneous n.		
		Median n.	Lateral root	C6–C7
			Medial root	
	Medial cord	Medial pectoral n.		C8–T1
		Medial antebrachial cutaneous n.		
		Medial brachial cutaneous n.		T1
		Ulnar n.		C7–T1
	Posterior cord	Upper subscapular n.		C5–C6
		Thoracodorsal n.		C6–C8
		Lower subscapular n.		C5–C6
		Axillary n.		
		Radial n.		C5–T1

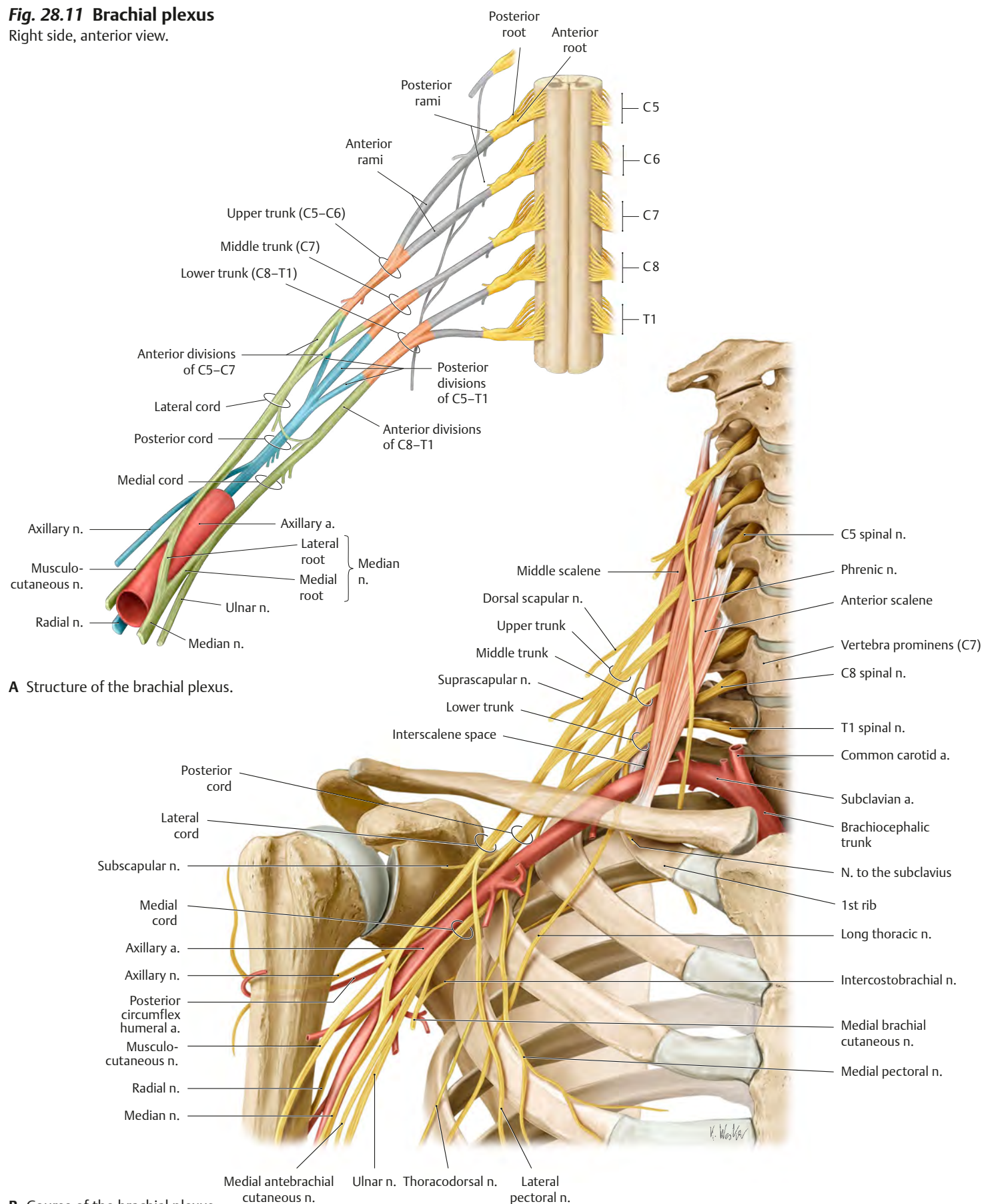
Clinical box 28.2

Injuries to nerves of the brachial plexus

Injuries of the brachial plexus can be complicated to diagnose but an understanding of the basic organization of the plexus is essential. The location of the injury can be determined by careful examination of the type and specificity of the deficit. Nerves of the upper plexus innervate muscles of the proximal limb such as those of the shoulder girdle and arm, while nerves of the lower plexus innervate muscles of the distal limb, such as the forearm and hand. Symptoms from injuries at the root and cord levels will demonstrate this anatomical arrangement. Additionally, a proximal injury to a nerve will elicit more broad-ranging symptoms than a distal injury to that nerve.

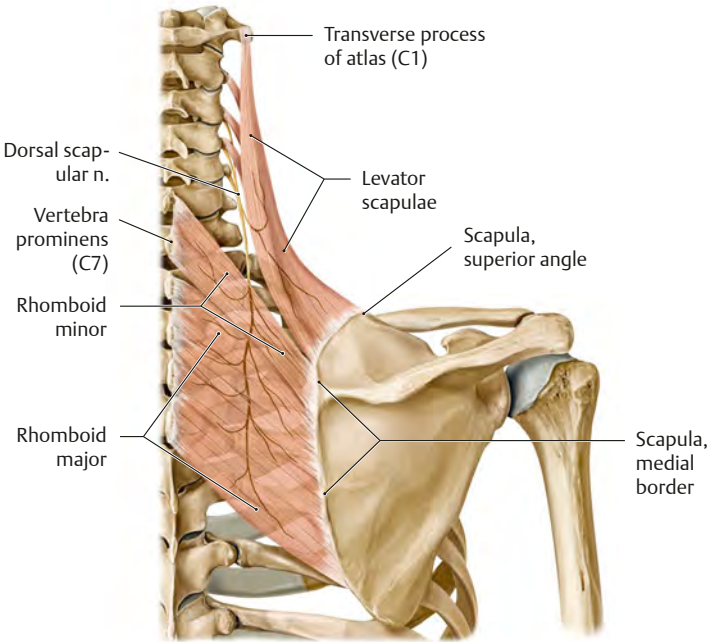
Fig. 28.11 Brachial plexus

Right side, anterior view.

**A** Structure of the brachial plexus.**B** Course of the brachial plexus, stretched for clarity.

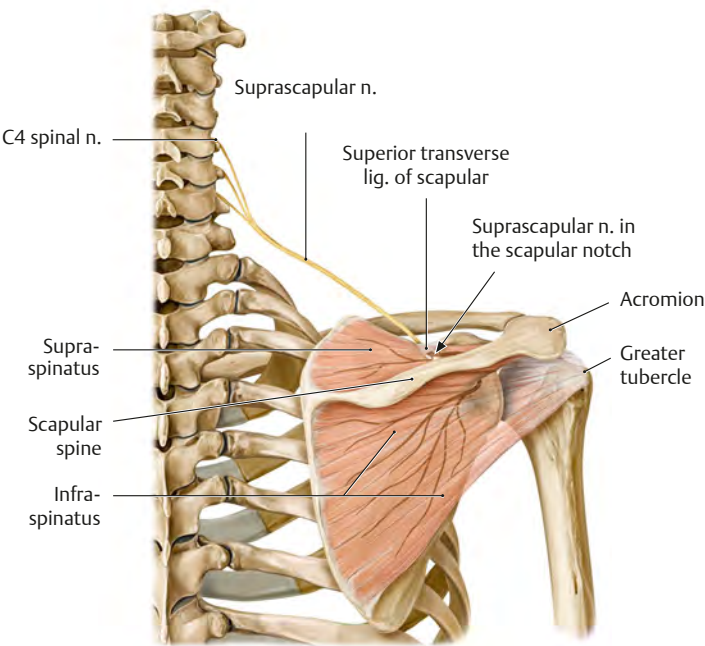
Supraclavicular Branches & Posterior Cord

Fig. 28.12 Supraclavicular branches
Right shoulder.

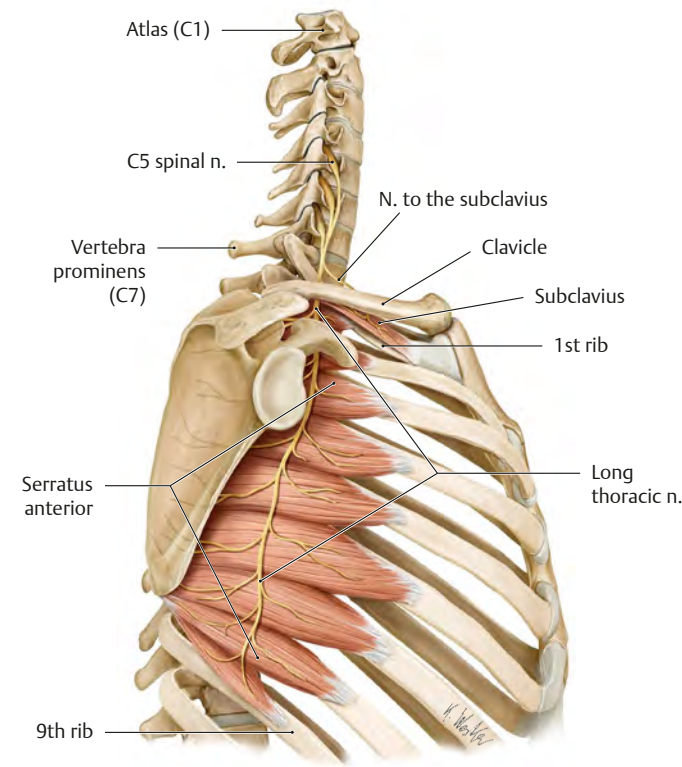


A Dorsal scapular nerve. Posterior view.

The supraclavicular branches of the brachial plexus arise directly from the plexus roots (anterior rami of the spinal nerves) or from the plexus trunks in the lateral cervical triangle.



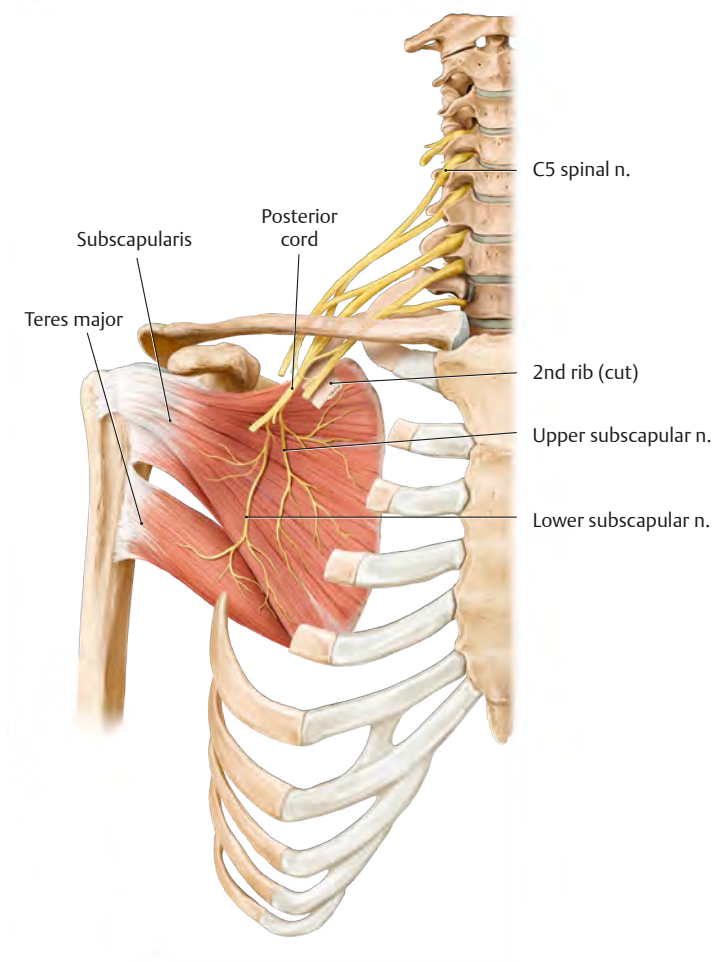
B Suprascapular nerve. Posterior view.



C Long thoracic nerve and nerve to the subclavius. Right lateral view.

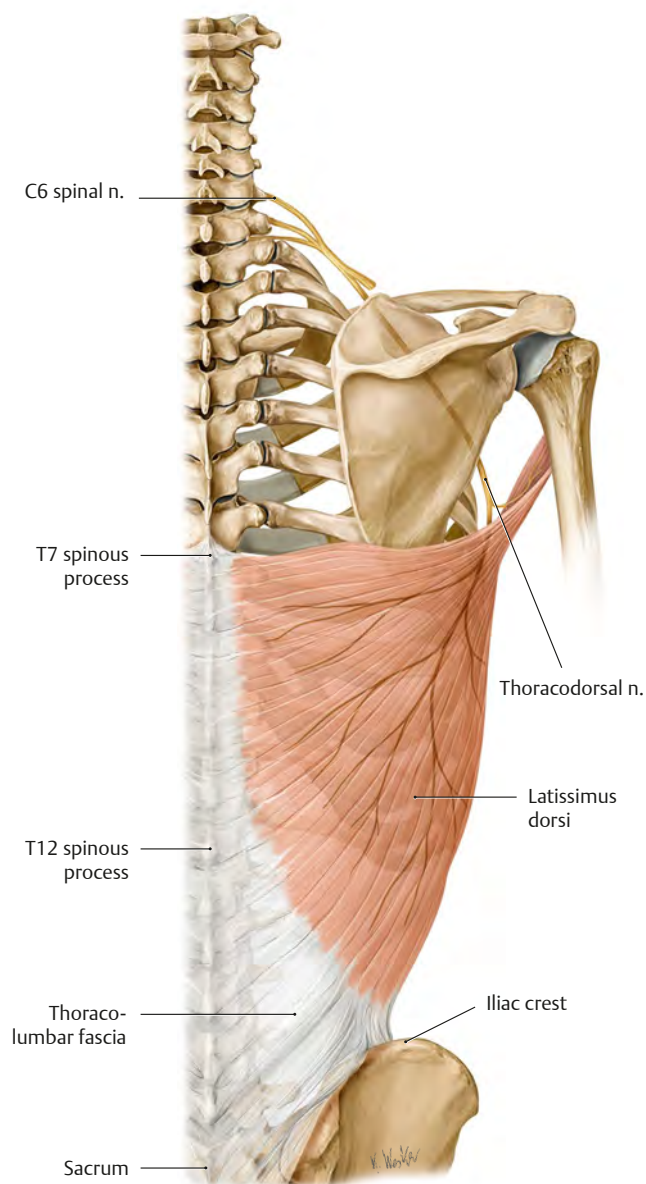
Table 28.2 Supraclavicular branches		
Nerve	Level	Innervated muscle
Dorsal scapular n.	C4–C5	Levator scapulae Rhomboids major and minor
Suprascapular n.	C5, C6	Supraspinatus Infraspinatus
N. to the subclavius	C5–C6	Subclavius
Long thoracic n.	C5–C7	Serratus anterior

Fig. 28.13 Posterior cord: Short branches
Right shoulder.



A Subscapular nerves. Anterior view.

The posterior cord gives off three short branches (arising at the level of the plexus cords) and two long branches (terminal nerves, see pp. 372–373).



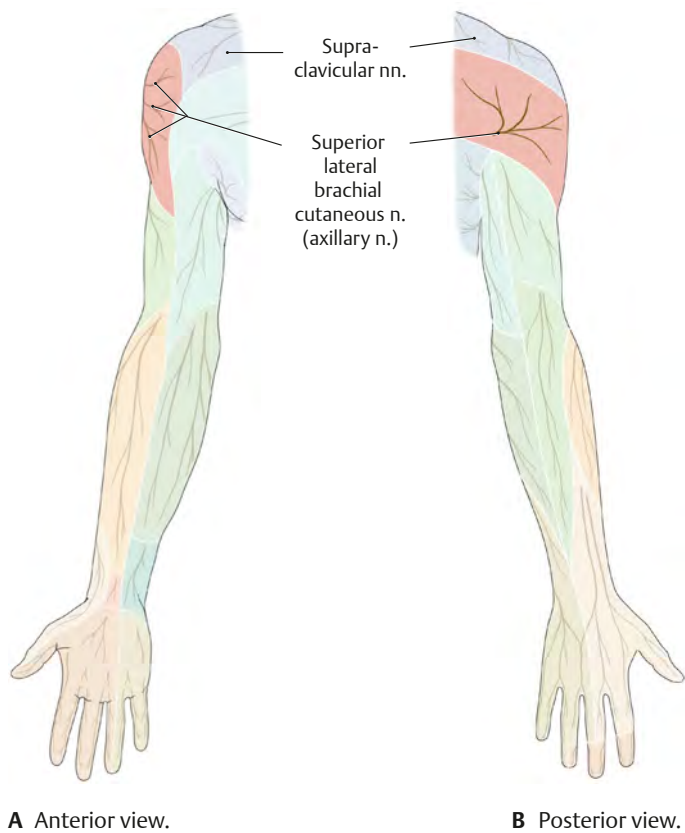
B Thoracodorsal nerve. Posterior view.

Table 28.3 Branches of the posterior cord

Nerve	Level	Innervated muscle
Short branches		
Upper subscapular n.	C5–C6	Subscapularis
Lower subscapular n.		Subscapularis Teres major
Thoracodorsal n.	C6–C8	Latissimus dorsi
Long (terminal) branches		
Axillary n.	C5–C6	See p. 372
Radial n.	C5–T1	See p. 373

Posterior Cord: Axillary & Radial Nerves

Fig. 28.14 Axillary nerve: Cutaneous distribution
Right limb.



 **Clinical box 28.3**

The axillary nerve may be damaged in a fracture of the surgical neck of the humerus. This results in limited ability to abduct the arm and may cause a loss of profile of the shoulder.

Fig. 28.15 Axillary nerve
Right side, anterior view, stretched for clarity.

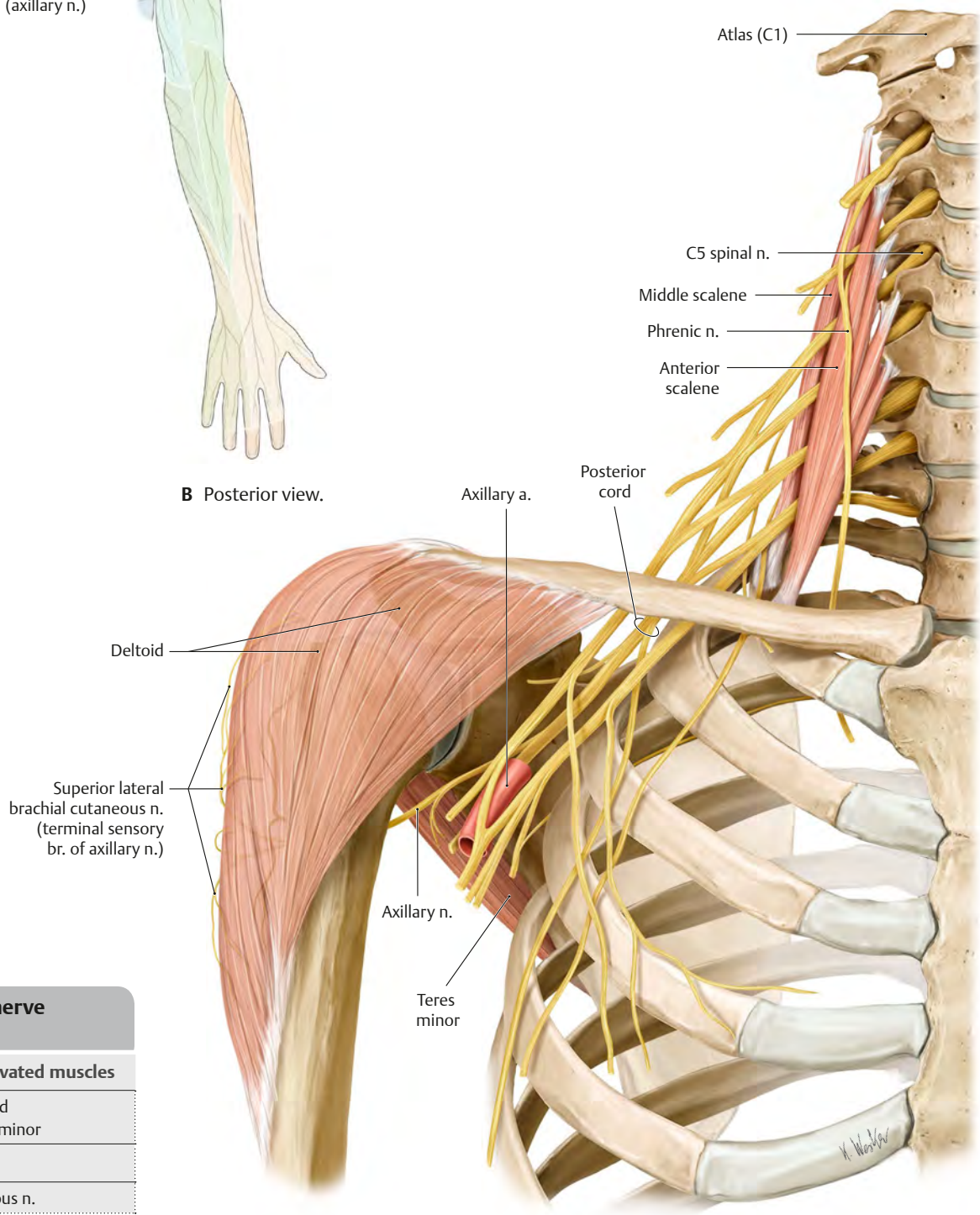
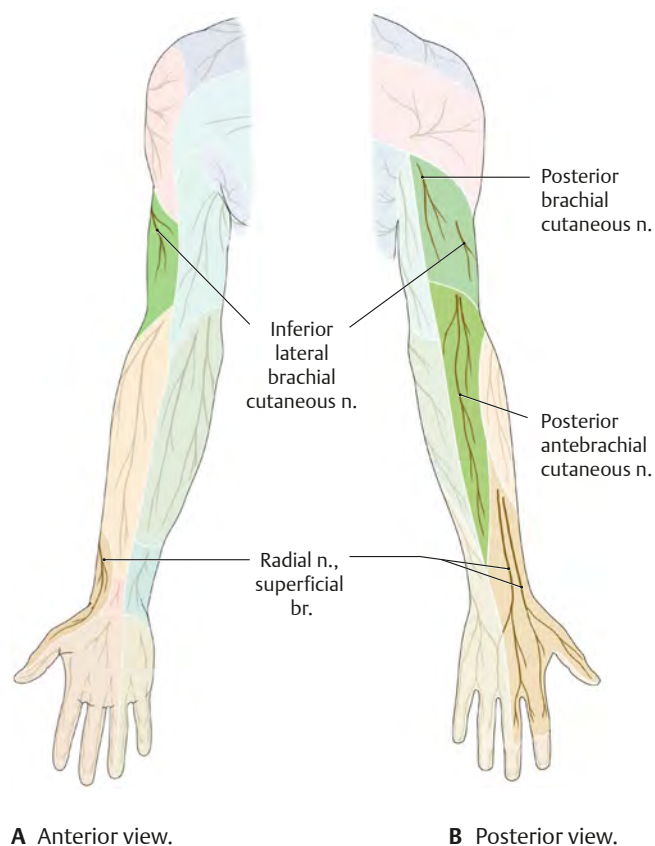


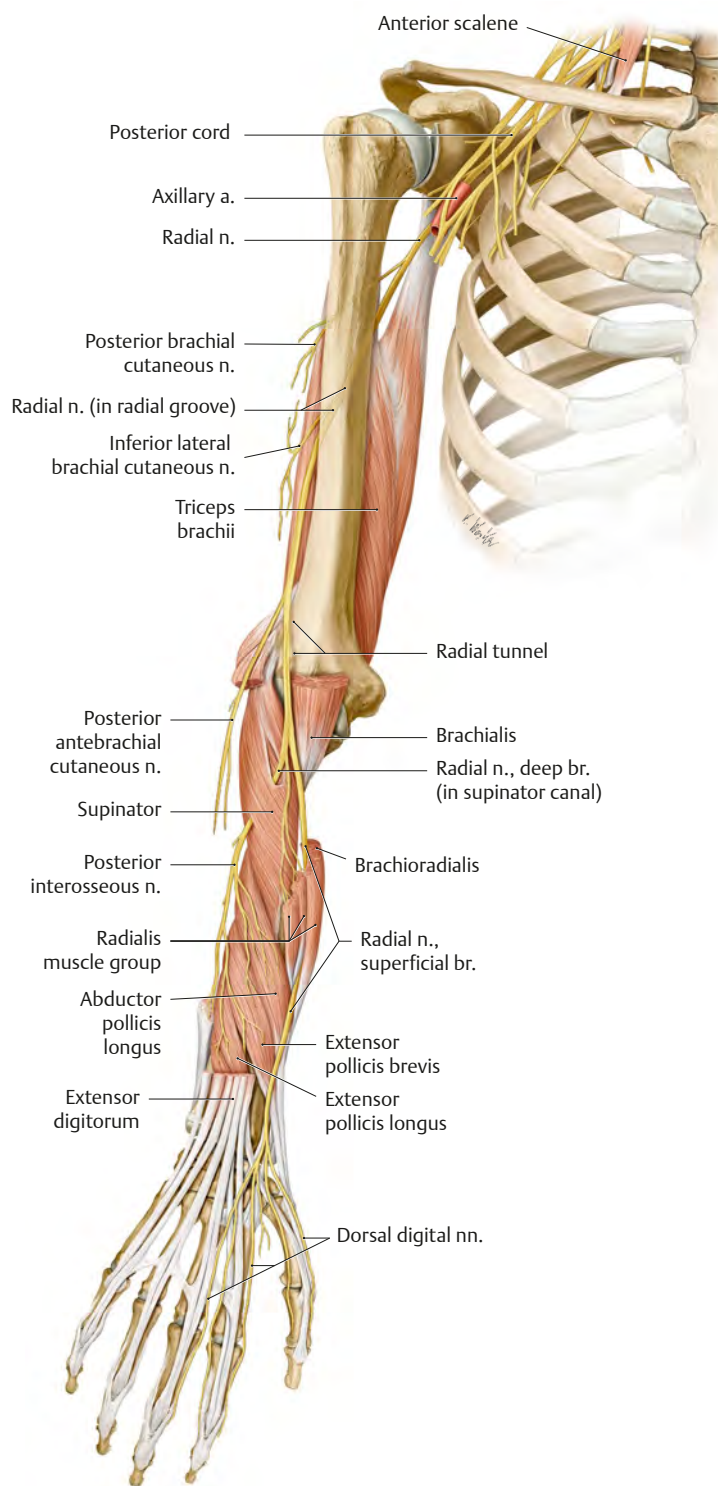
Table 28.4 Axillary nerve (C5–C6)	
Motor branches	Innervated muscles
Muscular brs.	Deltoid Teres minor
Sensory branch	
Superior lateral brachial cutaneous n.	

Fig. 28.16 Radial nerve: Cutaneous distribution**Table 28.5 Radial nerve (C5–T1)**

Motor branches	Innervated muscles
Muscular brs.	Brachialis (partial)
	Triceps brachii
	Anconeus
	Brachioradialis
	Extensors carpi radialis longus and brevis
Deep br. (terminal br.: posterior interosseous n.)	Supinator
	Extensor digitorum
	Extensor digiti minimi
	Extensor carpi ulnaris
	Extensors pollicis brevis and longus
	Extensor indicis
	Abductor pollicis longus
Sensory branches	
Articular brs. from radial n.: Capsule of the shoulder joint	
Articular brs. from posterior interosseous n.: Joint capsule of the wrist and four radial metacarpophalangeal joints	
Posterior brachial cutaneous n.	
Inferior lateral brachial cutaneous n.	
Posterior antebrachial cutaneous n.	
Superficial brs.	Dorsal digital nn.
	Ulnar communicating br.

Fig. 28.17 Radial nerve

Right limb, anterior view with forearm pronated.

**Clinical box 28.4**

Chronic radial nerve compression in the axilla (e.g., due to extended/improper crutch use) may cause loss of sensation or motor function in the hand, forearm, and posterior arm. More distal injuries (e.g., during anesthesia) affect fewer muscles, potentially resulting in wrist drop with intact triceps brachii function.

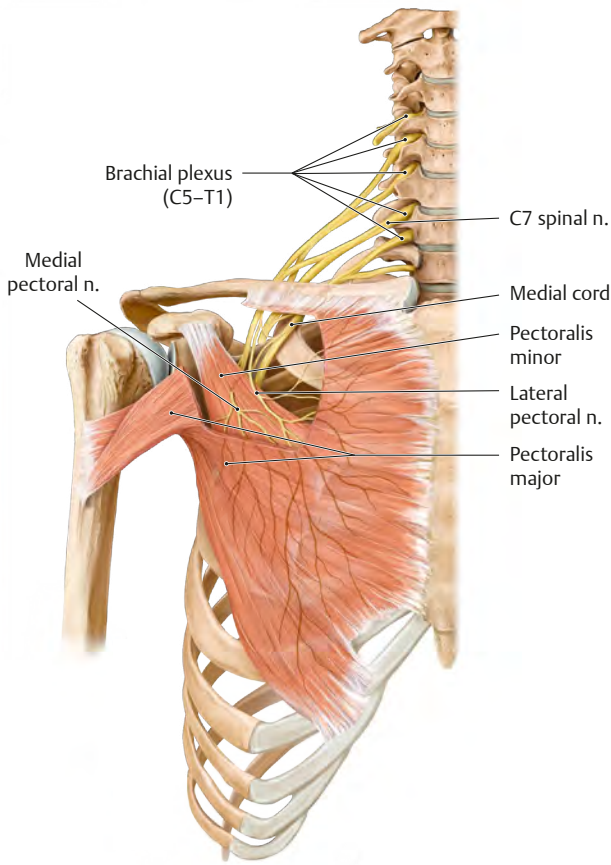
Medial & Lateral Cords

The medial and lateral cords give off four short branches. The intercostobrachial nerves are included with the short branches of the

brachial plexus, although they are actually the cutaneous branches of the 2nd and 3rd intercostal nerves.

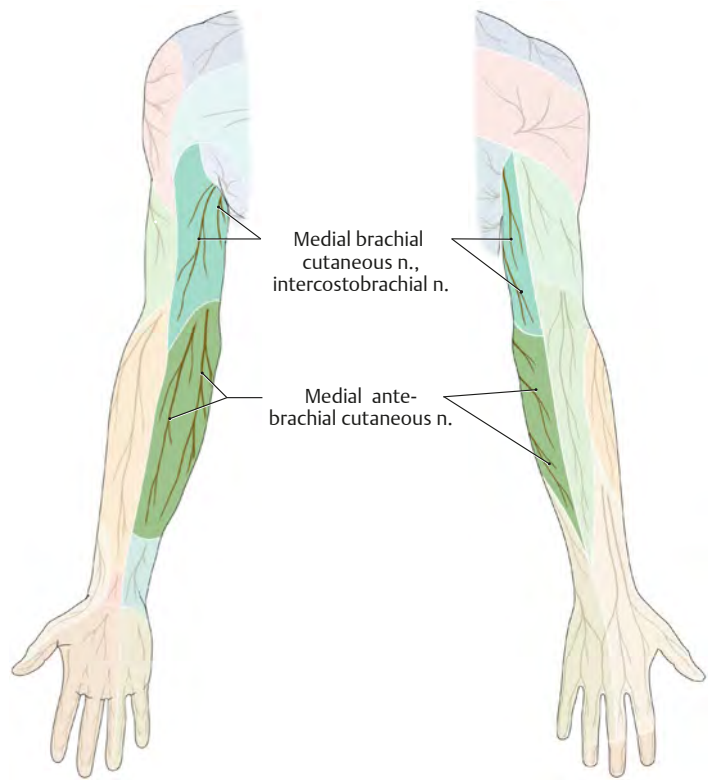
Table 28.6				Branches of the medial and lateral cords			
Nerve		Level		Cord		Innervated muscle	
Short branches							
Lateral pectoral n.		C5–C7		Lateral cord		Pectoralis major	
Medial pectoral n.		C8–T1		Medial cord		Pectoralis major and minor — (sensory brs., do not innervate any muscles)	
Medial brachial cutaneous n.		T1					
Medial antebrachial cutaneous n.		C8–T1					
Intercostobrachial nn.		T2–T3					
Long (terminal) branches							
Musculocutaneous n.		C5–C7		Lateral cord		Coracobrachialis Biceps brachii Brachialis	
Median n.		C6–T1		Medial cord		See p. 376	
Ulnar n.		C7–T1				See p. 377	

Fig. 28.18 Medial and lateral cords: Short branches
Right side, anterior view.



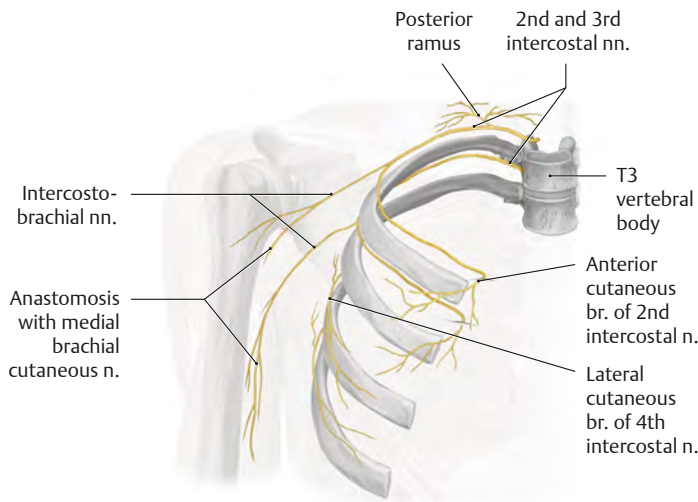
A Medial and lateral pectoral nerves.

Fig. 28.19 Short branches of medial and lateral cords: Cutaneous distribution



A Anterior view.

B Posterior view.



B Intercostobrachial nerves.

Fig. 28.20 Musculocutaneous nerve
Right limb, anterior view.

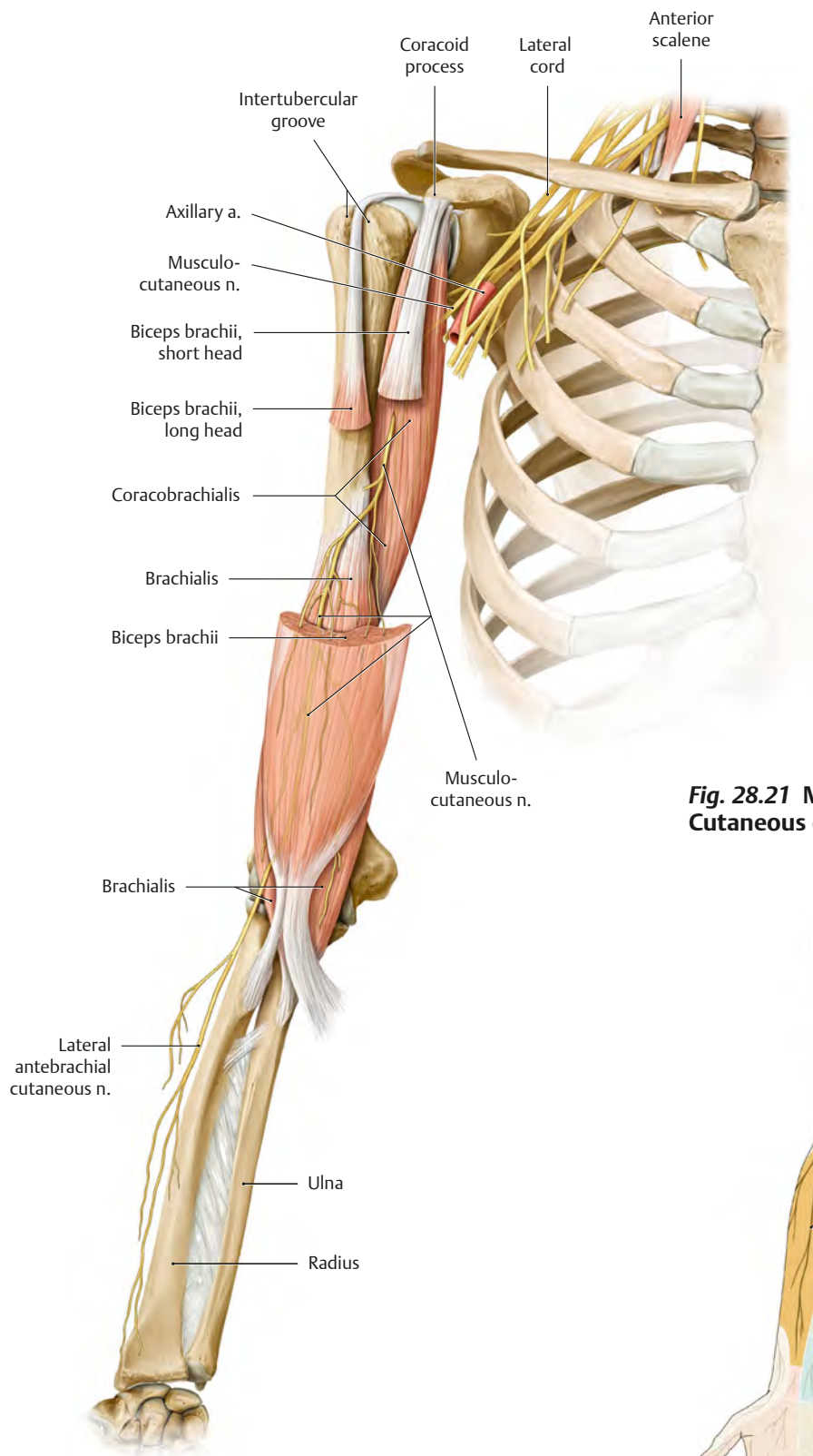
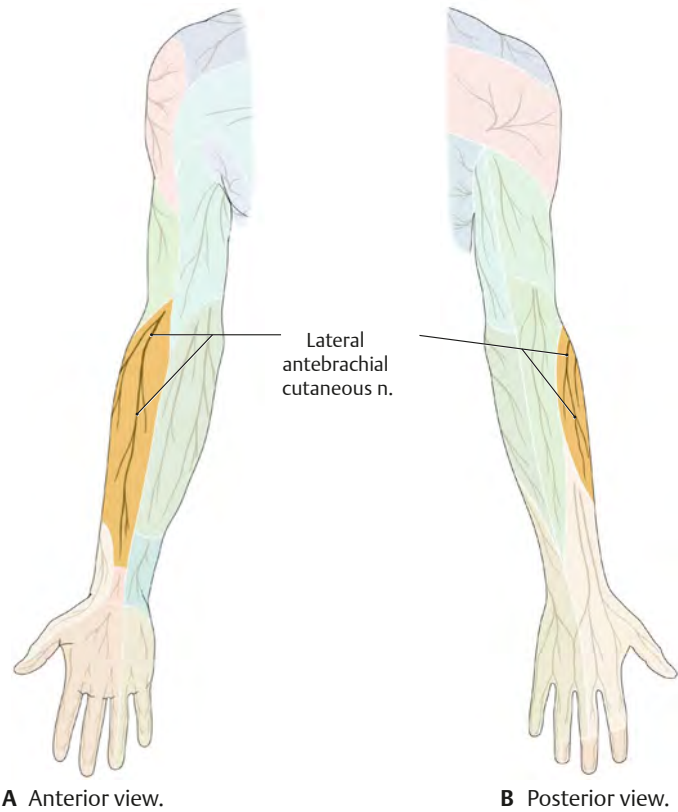


Table 28.7 Musculocutaneous nerve (C5–C7)	
Motor branches	Innervated muscles
Muscular brs.	Coracobrachialis
	Biceps brachii
	Brachialis
Sensory branches	
Lateral antebrachial cutaneous n.	
Articular brs.: Joint capsule of the elbow (anterior part)	
Note: Musculocutaneous n. innervation of the arm is purely motor; innervation of the forearm is purely sensory.	

Fig. 28.21 Musculocutaneous nerve: Cutaneous distribution



Median & Ulnar Nerves

The median nerve is a terminal branch arising from both the medial and the lateral cords. The ulnar nerve arises exclusively from the medial cord.

Fig. 28.22 Median nerve
Right limb, anterior view.

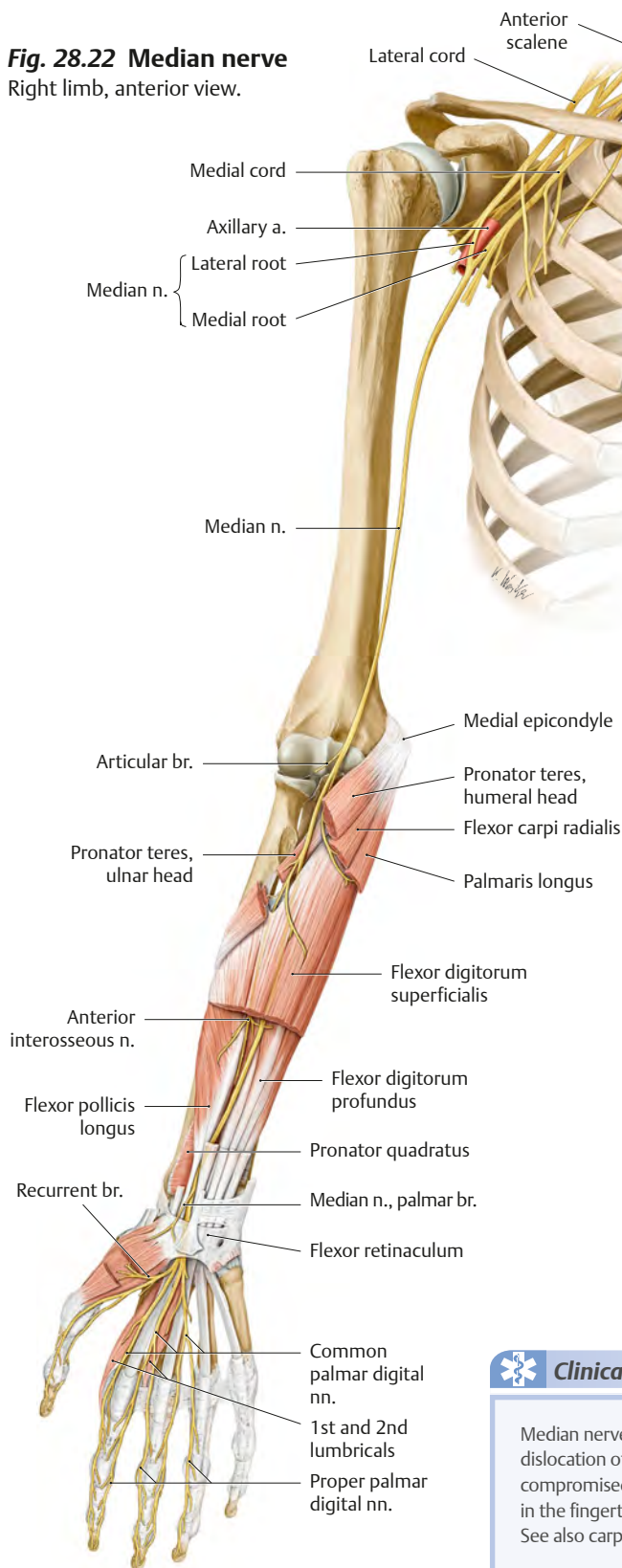


Fig. 28.23 Median nerve: Cutaneous distribution

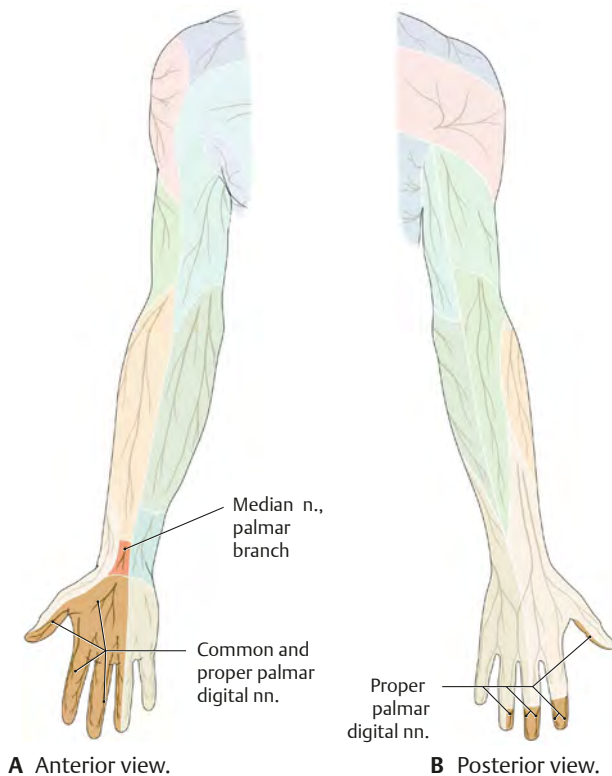
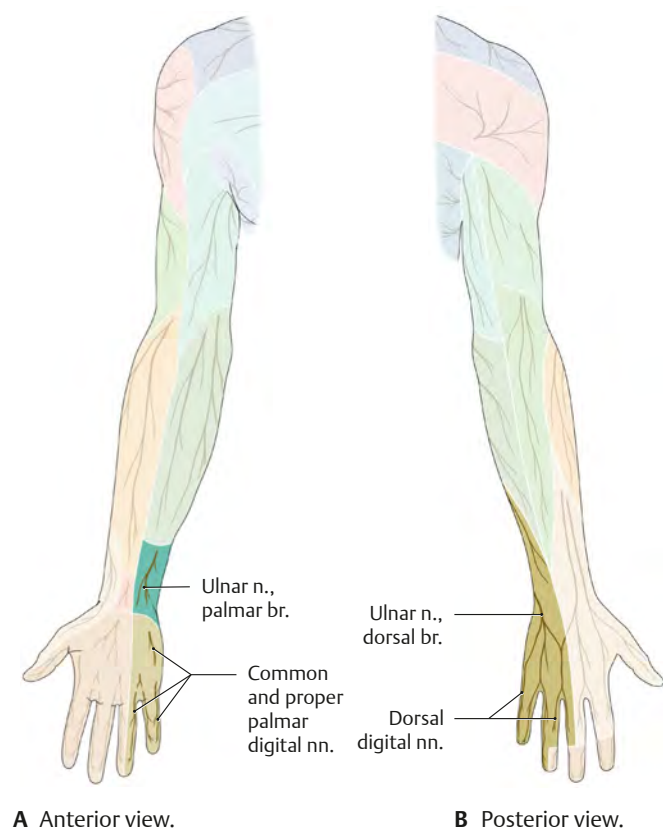
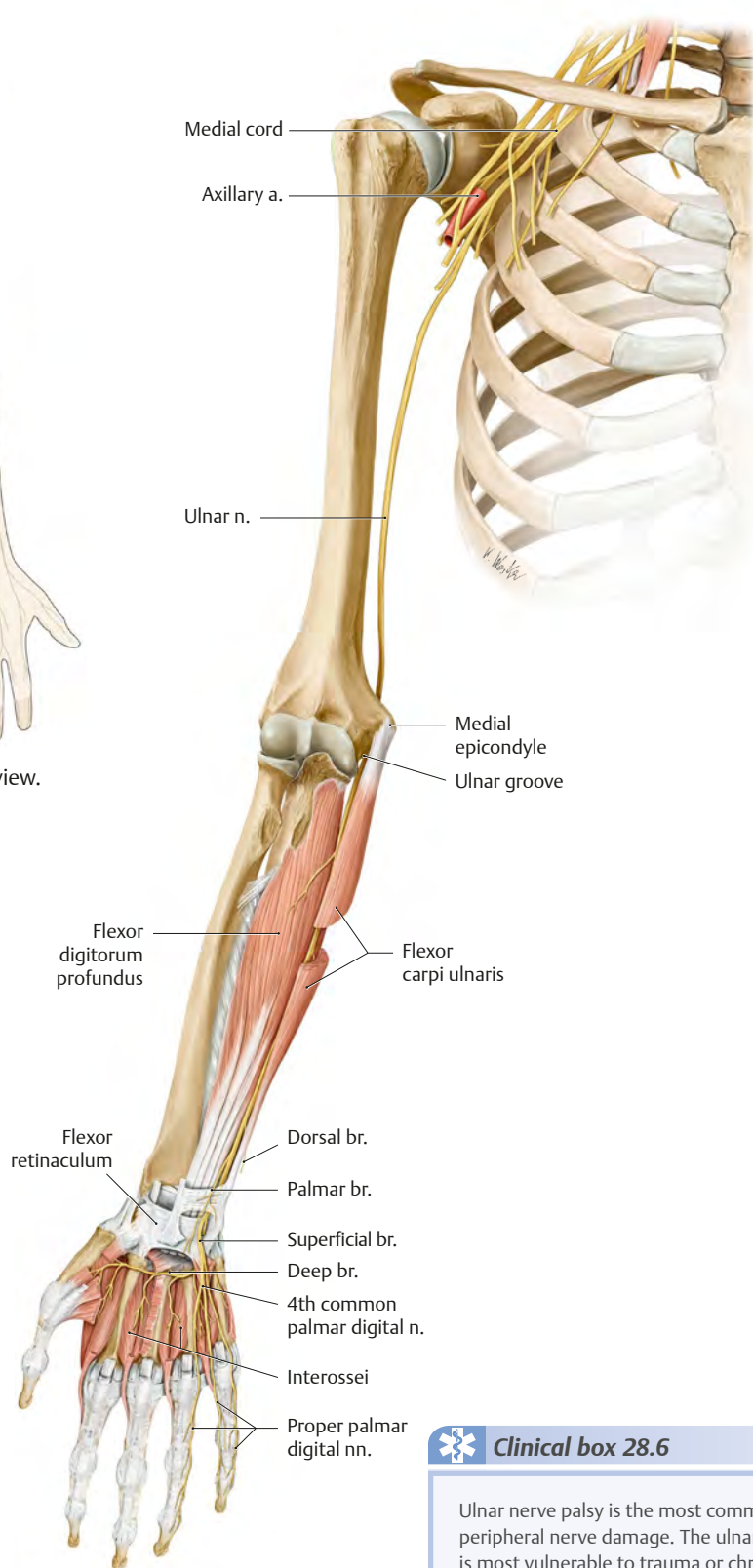


Table 28.8 Median nerve (C6–T1)	
Motor branches	Innervated muscles
Direct muscular brs.	Pronator teres
	Flexor carpi radialis
	Palmaris longus
Muscular brs. from anterior interosseous n.	Flexor digitorum superficialis
	Pronator quadratus
	Flexor pollicis longus
Recurrent br.	Flexor digitorum profundus (radial half)
	Abductor pollicis brevis
	Flexor pollicis brevis (superficial head)
Muscular brs. from common palmar digital nn.	Opponens pollicis
	1st and 2nd lumbricals
Sensory branches	
Articular brs.: Capsules of the elbow and wrist joints	
Palmar br. of median n. (thenar eminence)	
Communicating br. to ulnar n.	
Common palmar digital nn.	
Proper palmar digital nn.	



Clinical box 28.5

Median nerve injury caused by fracture/dislocation of the elbow joint may result in compromised grasping ability and sensory loss in the fingertips (see Fig. 28.23 for territories). See also carpal tunnel syndrome (p. 391).

Fig. 28.24 Ulnar nerve: Cutaneous distribution**Fig. 28.25 Ulnar nerve**
Right limb, anterior view.**Table 28.9 Ulnar nerve (C7–T1)**

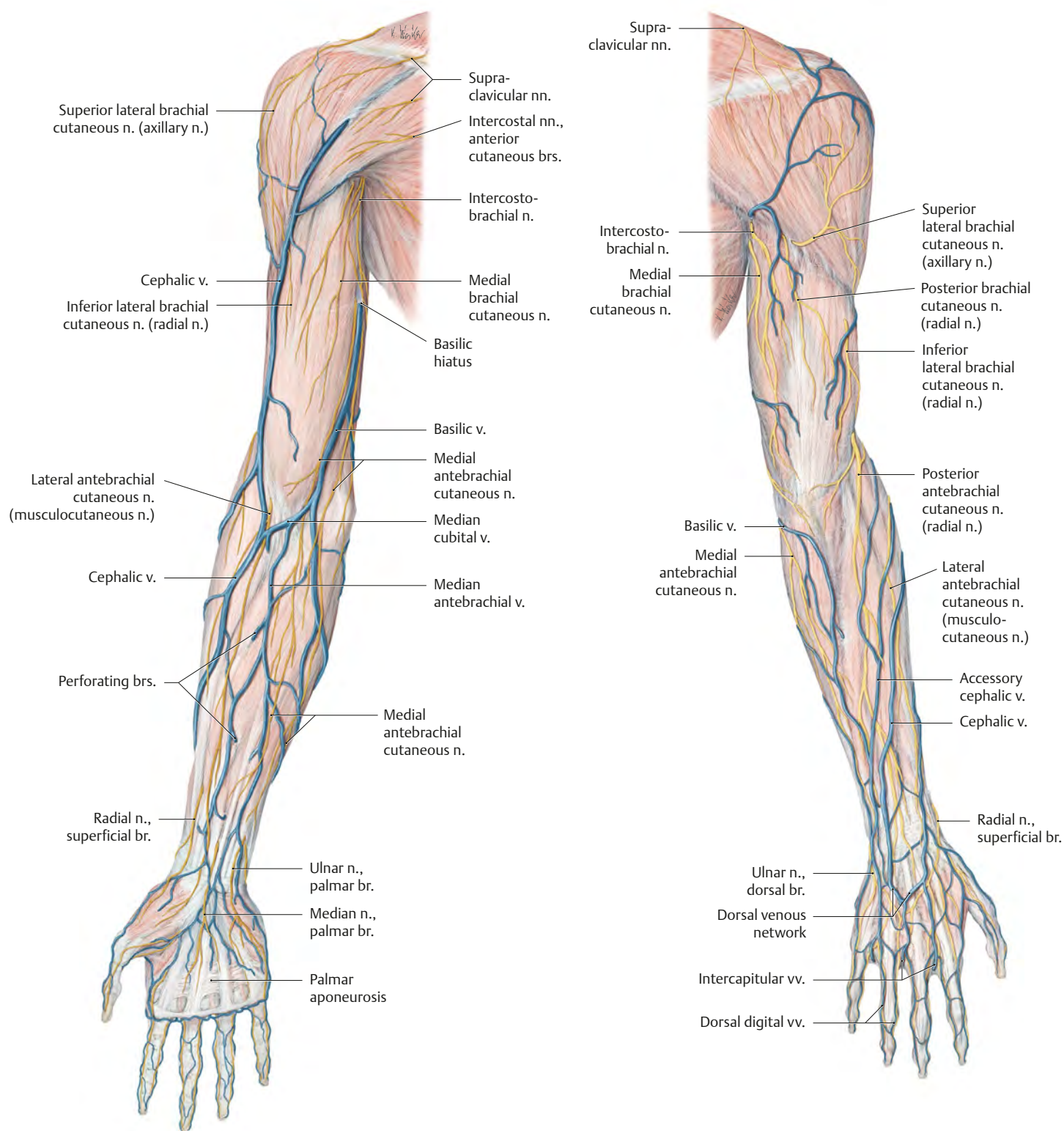
Motor branches	Innervated muscles
Direct muscular brs.	Flexor carpi ulnaris
	Flexor digitorum profundus (ulnar half)
Muscular br. from superior ulnar n.	Palmaris brevis
Muscular brs. from deep ulnar n.	Abductor digiti minimi
	Flexor digiti minimi brevis
	Opponens digiti minimi
	3rd and 4th lumbricals
	Palmar and dorsal interosseous muscles
	Adductor pollicis
	Flexor pollicis brevis (deep head)
Sensory branches	
Articular brs.: Capsules of the elbow, carpal, and metacarpophalangeal joints	
Dorsal br. (terminal brs.: dorsal digital nn.)	
Palmar br.	
Proper palmar digital n. (from superficial br.)	
Common palmar digital n. (from superficial br.; terminal brs.: proper palmar digital nn.)	

**Clinical box 28.6**

Ulnar nerve palsy is the most common peripheral nerve damage. The ulnar nerve is most vulnerable to trauma or chronic compression in the elbow joint and ulnar tunnel (see **p. 391**). Nerve damage causes “clawing” of the hand and atrophy of the interossei. Sensory losses are often limited to the 5th digit.

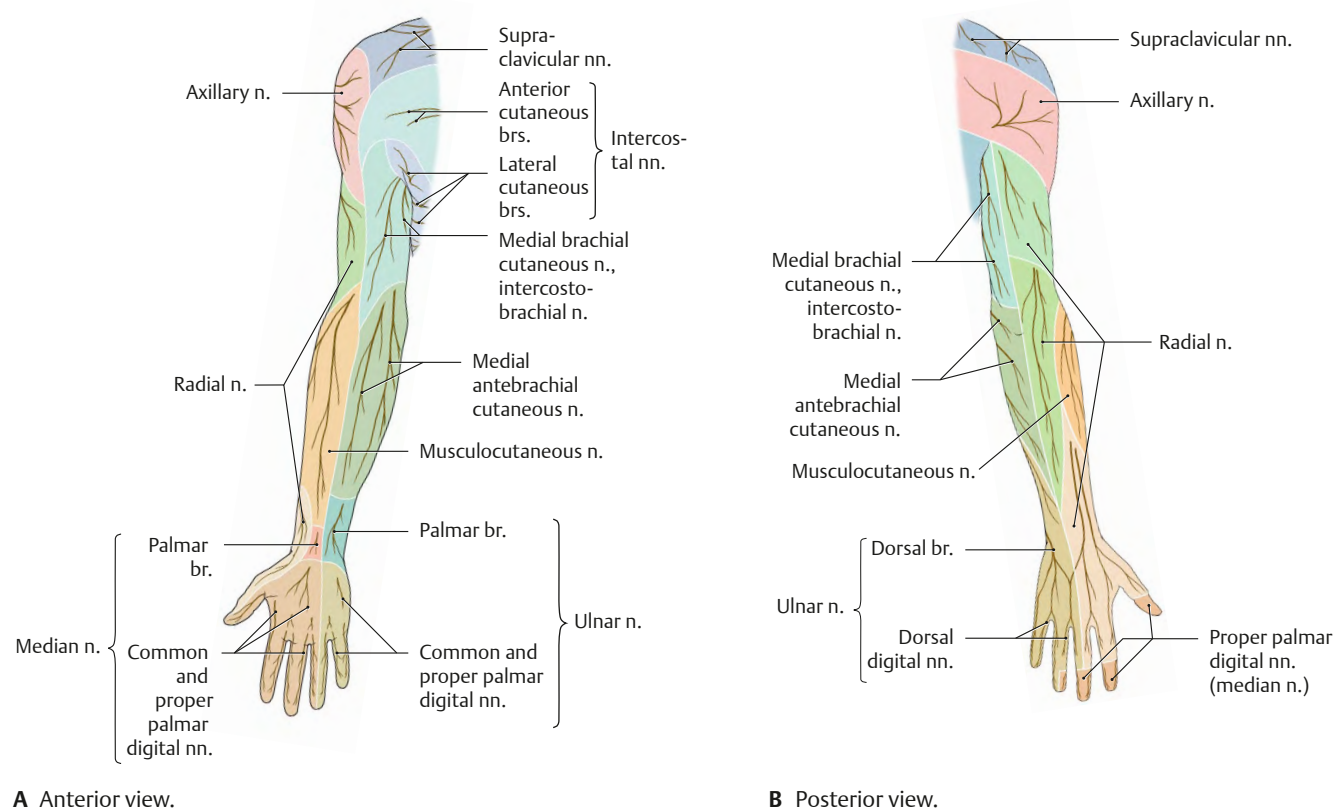
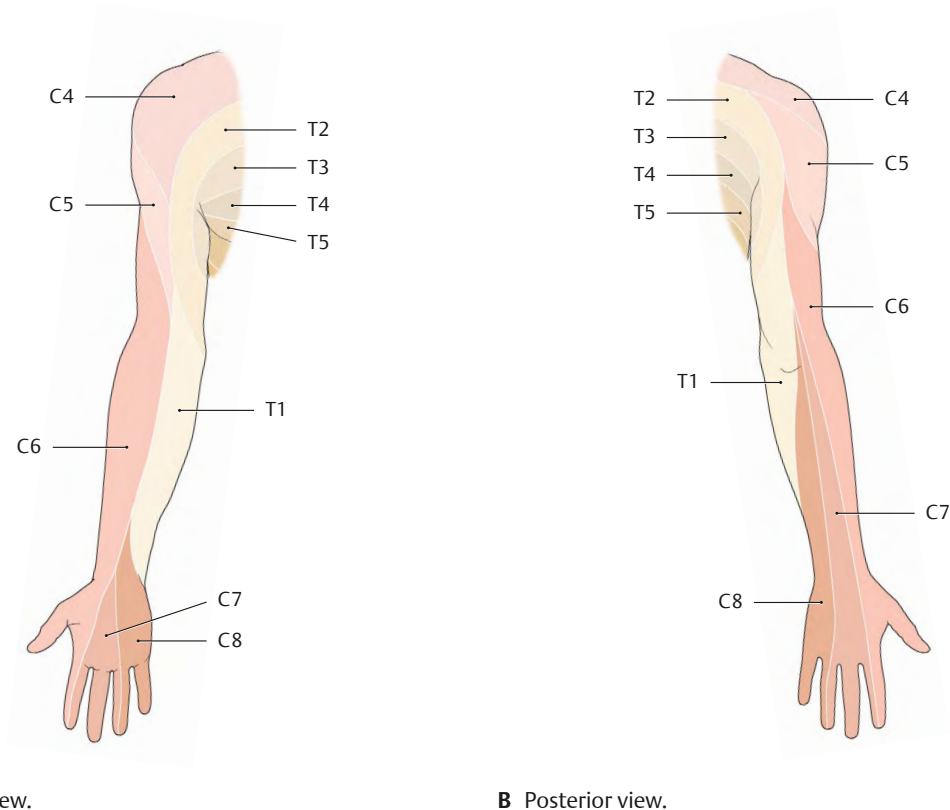
Superficial Veins & Nerves of the Upper Limb

Fig. 28.26 Superficial cutaneous veins and nerves of the upper limb



A Anterior view. See pp. 392–393 for nerves of the palm.

B Posterior view. See pp. 394–395 for nerves of the dorsum.

Fig. 28.27 Cutaneous innervation of the upper limb**Fig. 28.28 Dermatomes of the upper limb**

Posterior Shoulder & Arm

Fig. 28.29 Posterior shoulder

Right shoulder, posterior view. *Raised:* Trapezius (transverse part).

Windowed: Supraspinatus. *Revealed:* Suprascapular region.

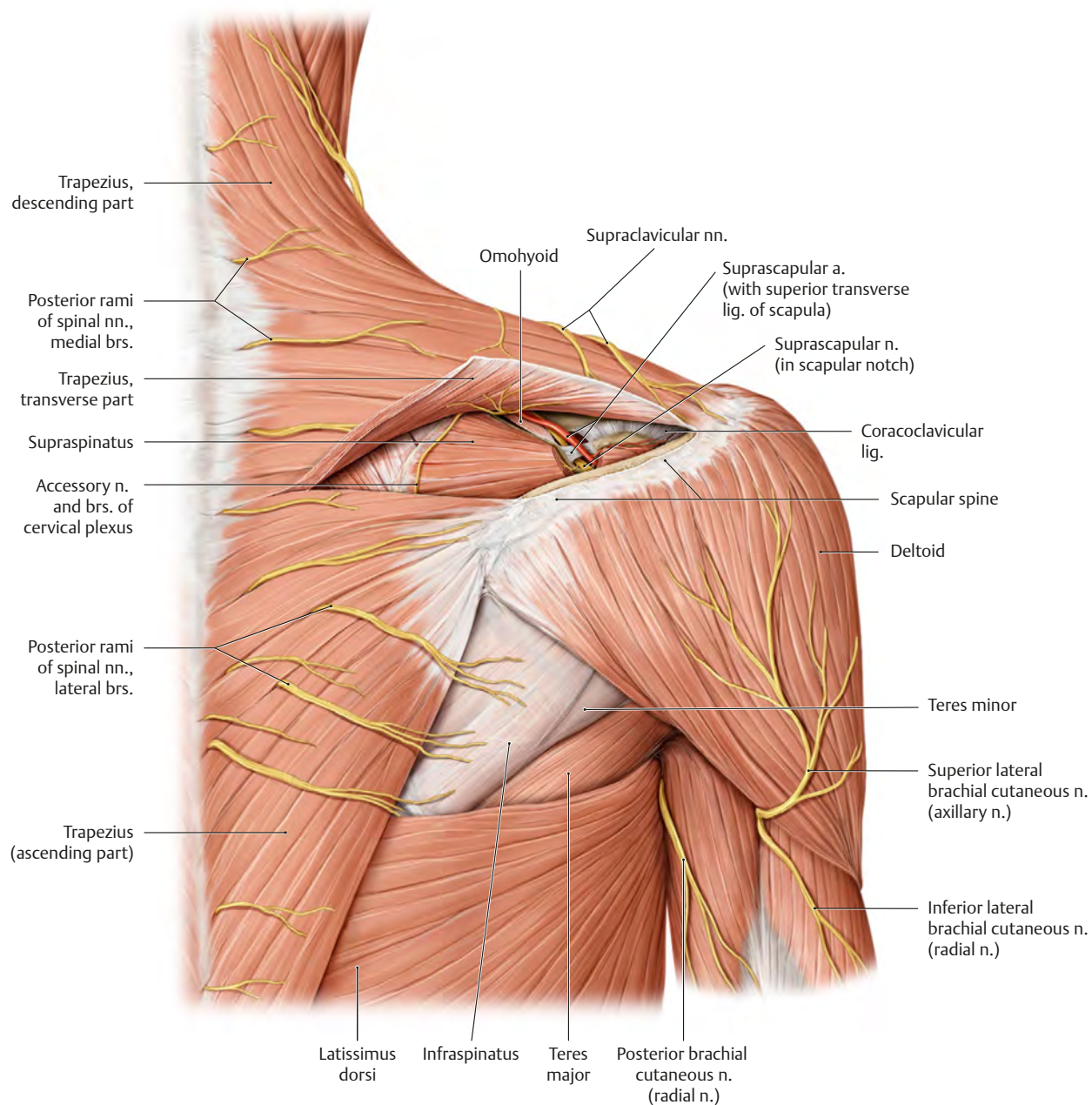


Table 28.10 Neurovascular tracts of the scapula

Passageway	Boundaries	Transmitted structures
① Scapular notch	Superior transverse lig. of scapula, scapula	Suprascapular a., v. and n.
② Medial border	Scapula	Dorsal scapular a., v. and n.
③ Triangular space	Teres major and minor, triceps brachii	Circumflex scapular a. and v.
④ Triceps hiatus	Triceps brachii, humerus, teres major	Deep a. and v. of arm and radial n.
⑤ Quadrangular space	Teres major and minor, triceps brachii, humerus	Posterior circumflex humeral a. and v. and axillary n.

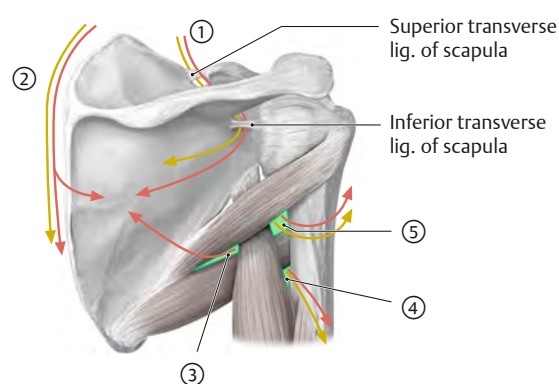
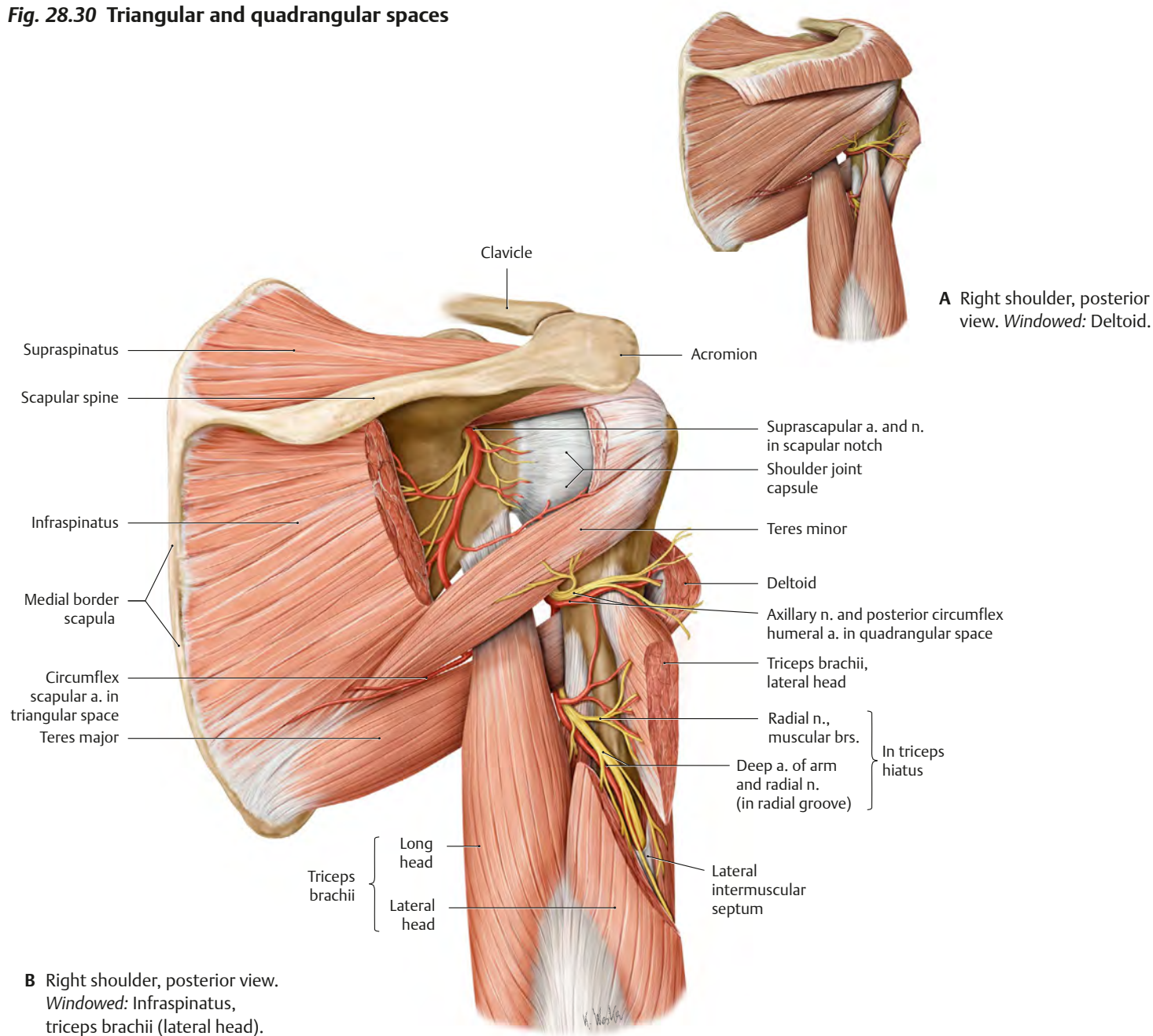
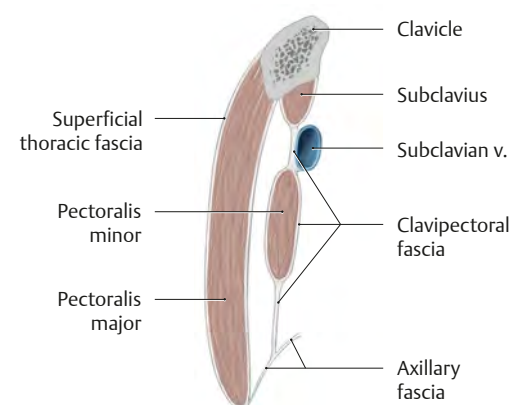


Fig. 28.30 Triangular and quadrangular spaces

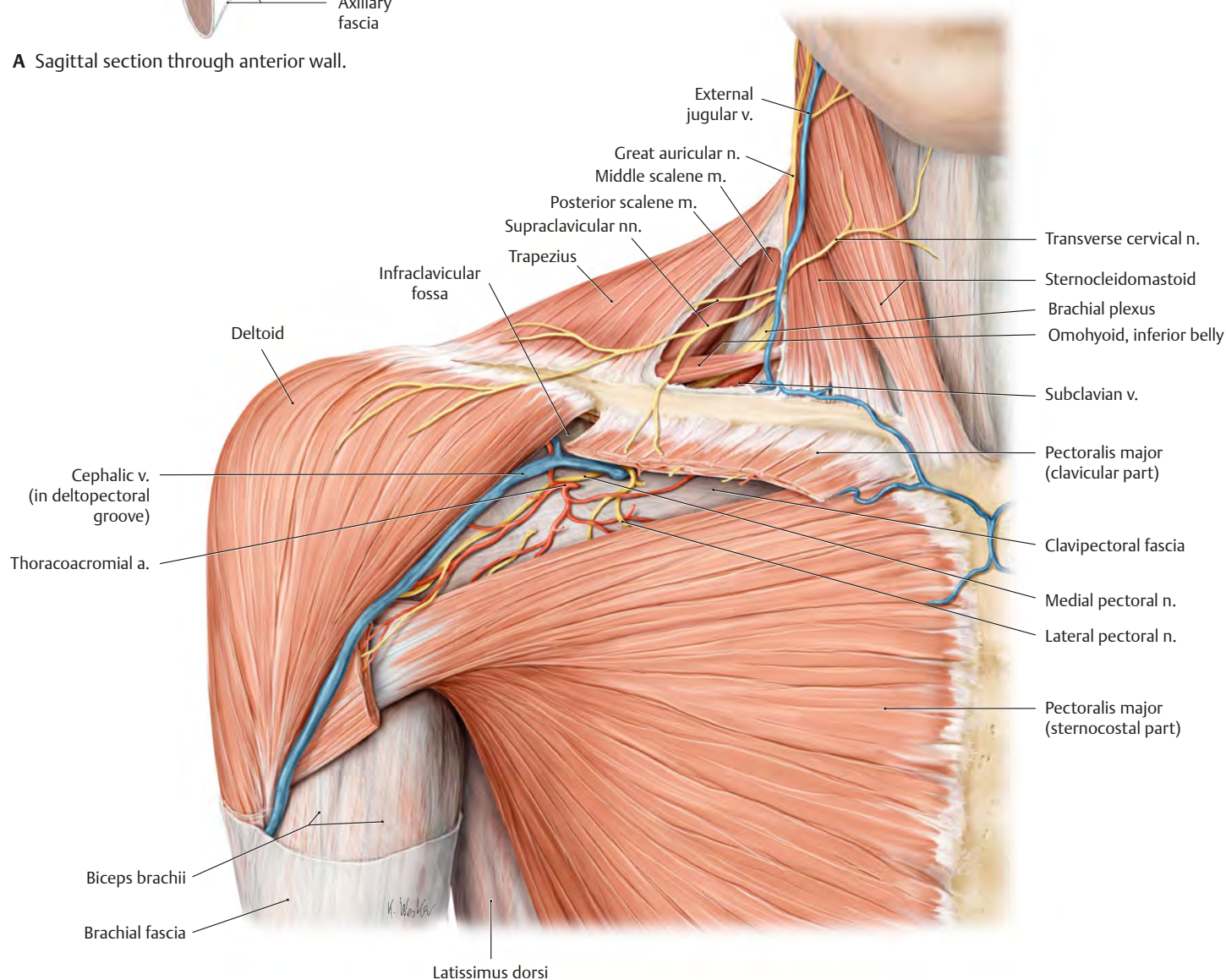


Anterior Shoulder

Fig. 28.31 Anterior shoulder: Superficial dissection
Right shoulder.



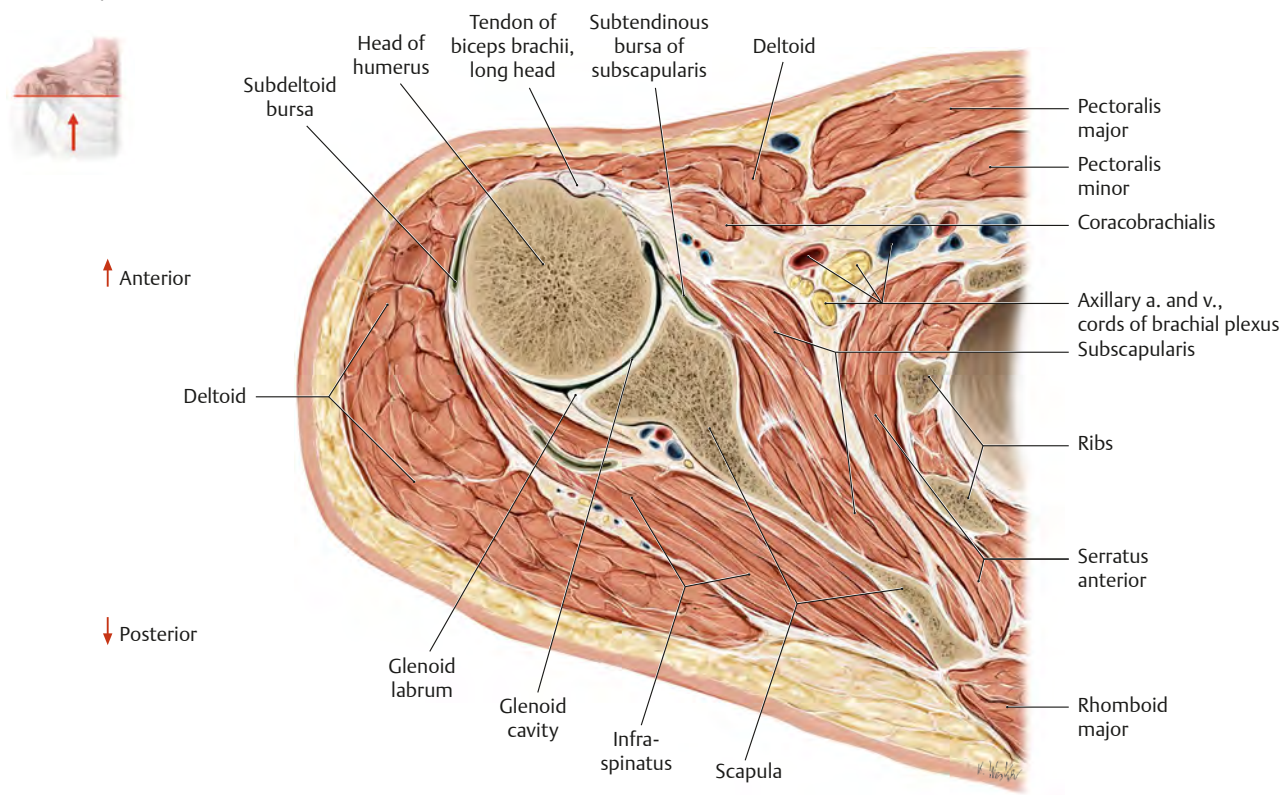
A Sagittal section through anterior wall.



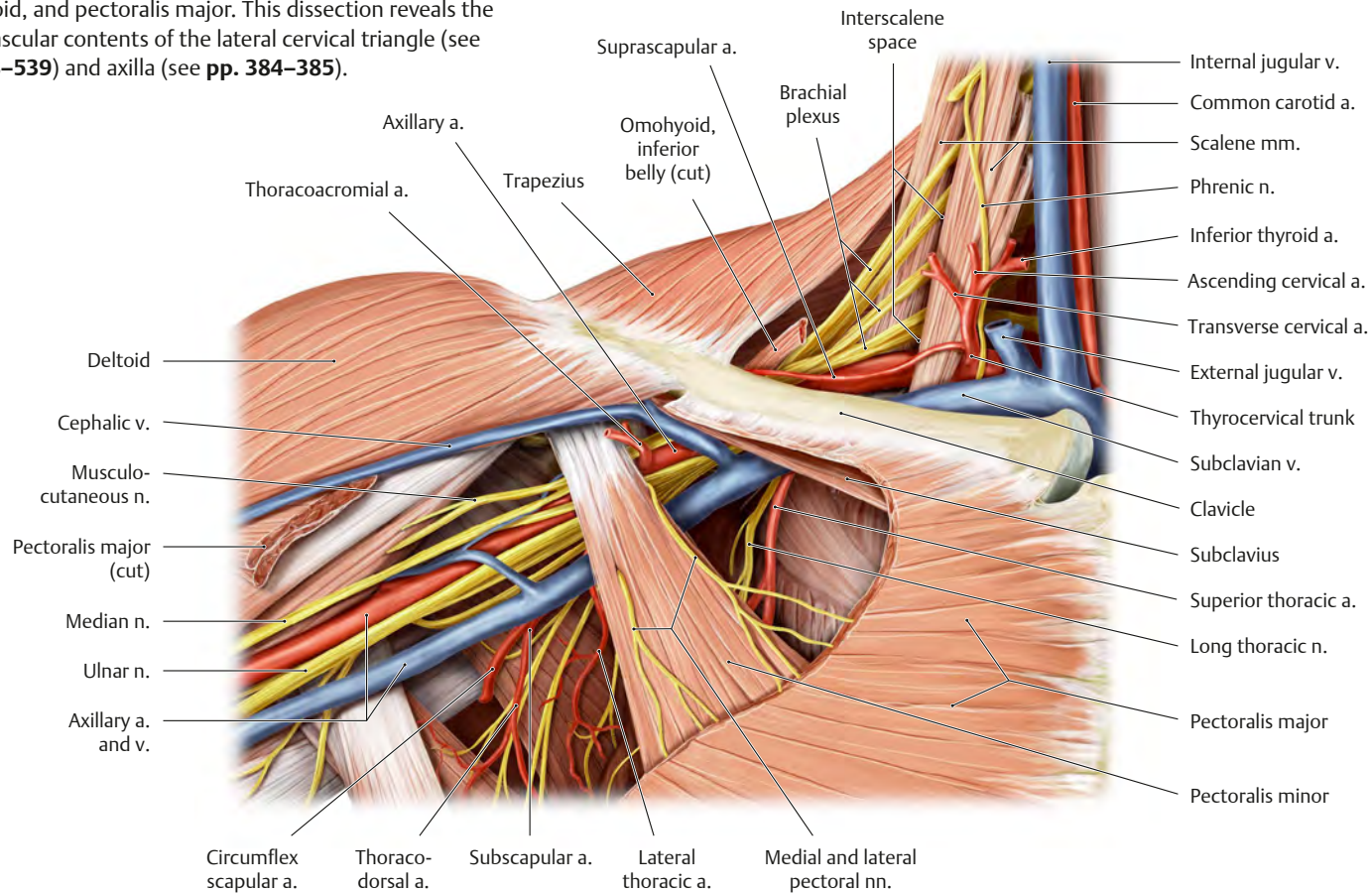
B Anterior view. *Removed:* Platysma, muscle fasciae, superficial layer of cervical fascia, and pectoralis major (clavicular part).
Revealed: Clavipectoral triangle.

Fig. 28.32 Shoulder: Transverse section

Right shoulder, inferior view.

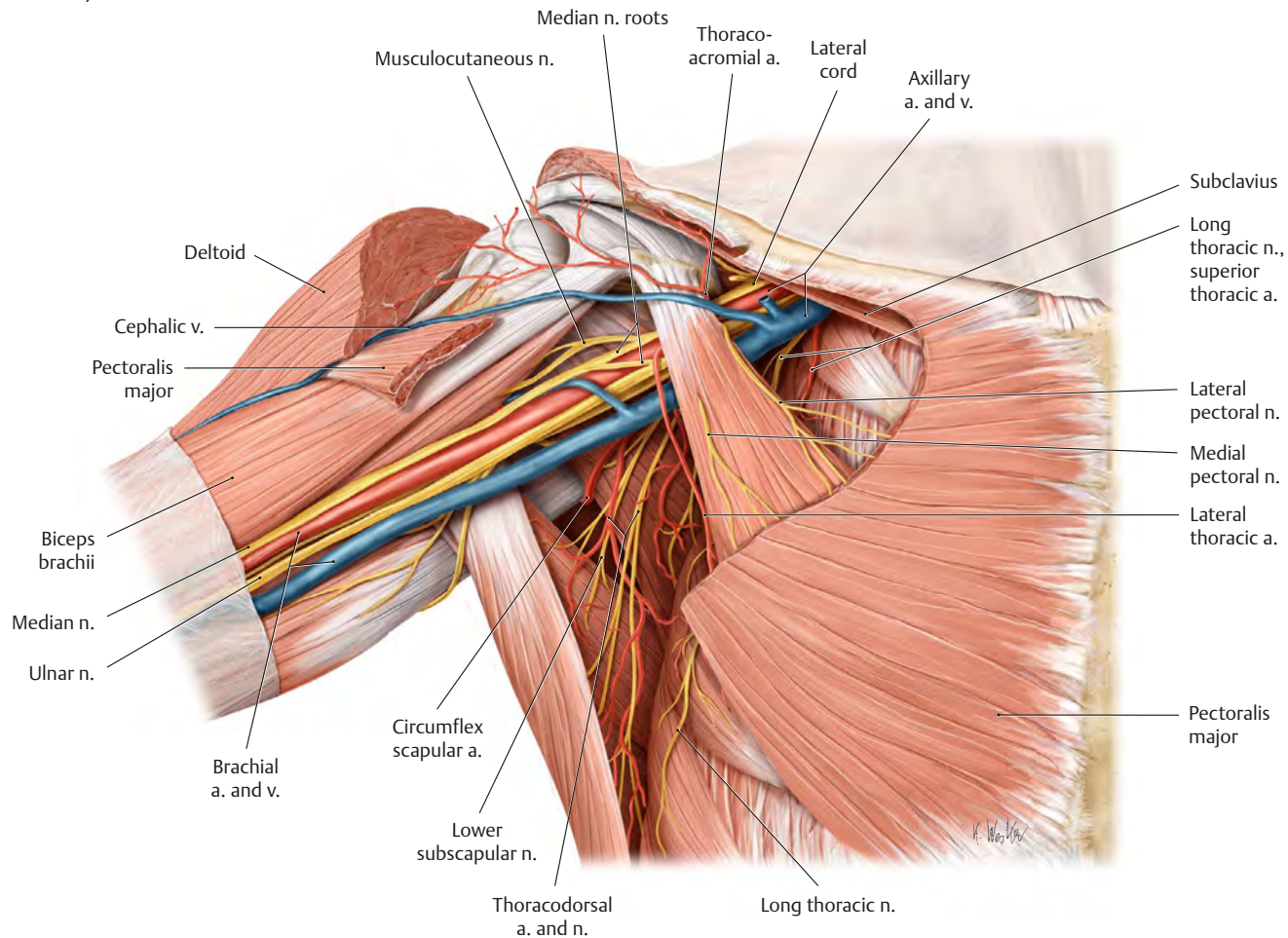
**Fig. 28.33 Anterior shoulder: Deep dissection**

Right limb, anterior view. *Removed:* Sternocleidomastoid, omohyoid, and pectoralis major. This dissection reveals the neurovascular contents of the lateral cervical triangle (see pp. 538–539) and axilla (see pp. 384–385).



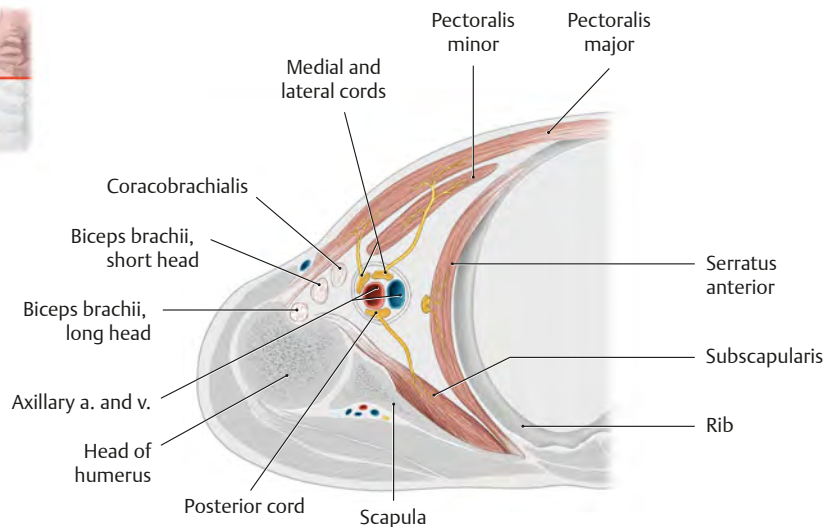
Axilla

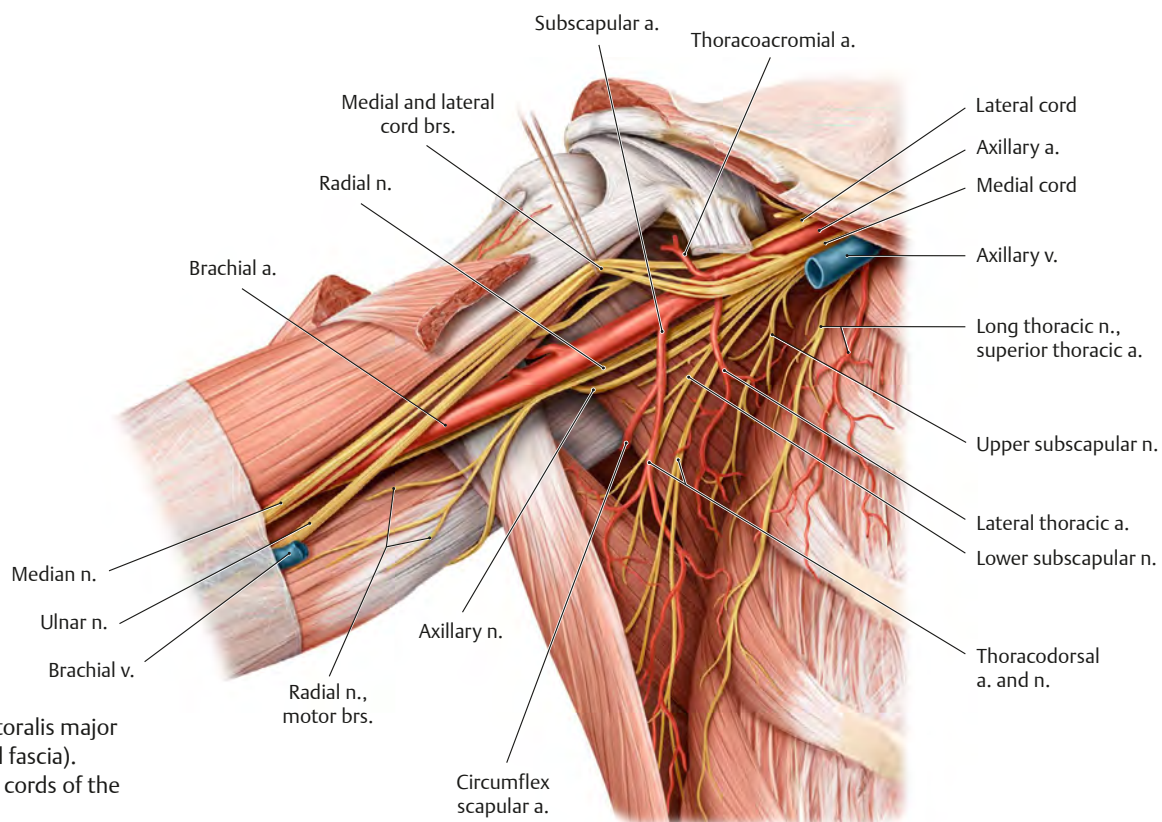
Fig. 28.34 Axilla: Dissection
Right shoulder, anterior view.



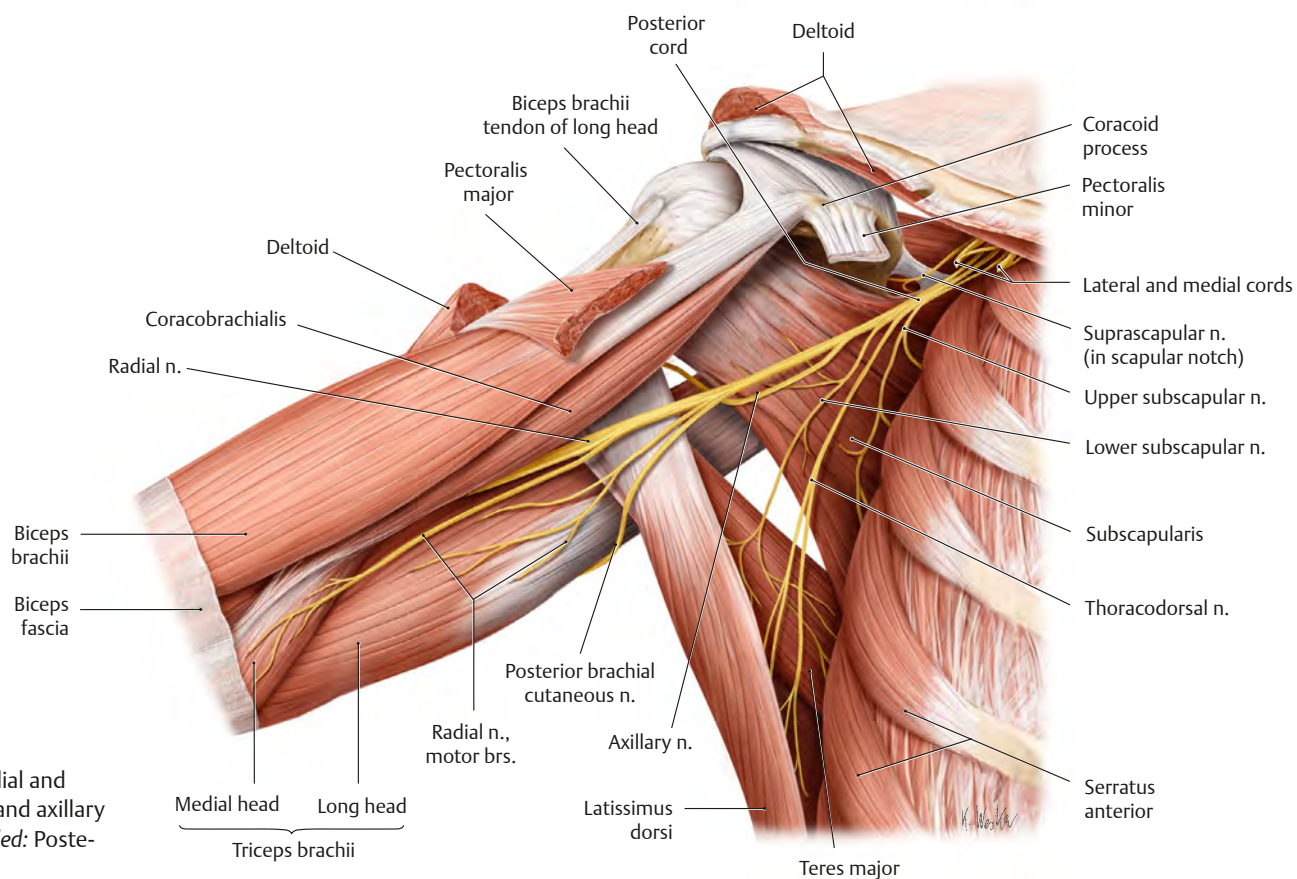
A Removed: Pectoralis major and clavipectoral fascia.

Table 28.11	Walls of the axilla
Anterior wall	Pectoralis major Pectoralis minor Clavipectoral fascia
Lateral wall	Intertubercular groove of humerus
Posterior wall	Subscapularis Teres major Latissimus dorsi
Medial wall	Lateral thoracic wall Serratus anterior





B *Removed:* Anterior wall (pectoralis major and minor, and clavipectoral fascia).
Retracted: Medial and lateral cords of the brachial plexus.



C *Removed:* Medial and lateral cords, and axillary vessels. *Revealed:* Posterior cord.

Anterior Arm & Cubital Region

Fig. 28.35 Brachial region

Right arm, anterior view. *Removed:* Deltoid, pectoralis major and minor. *Revealed:* Medial bicipital groove.

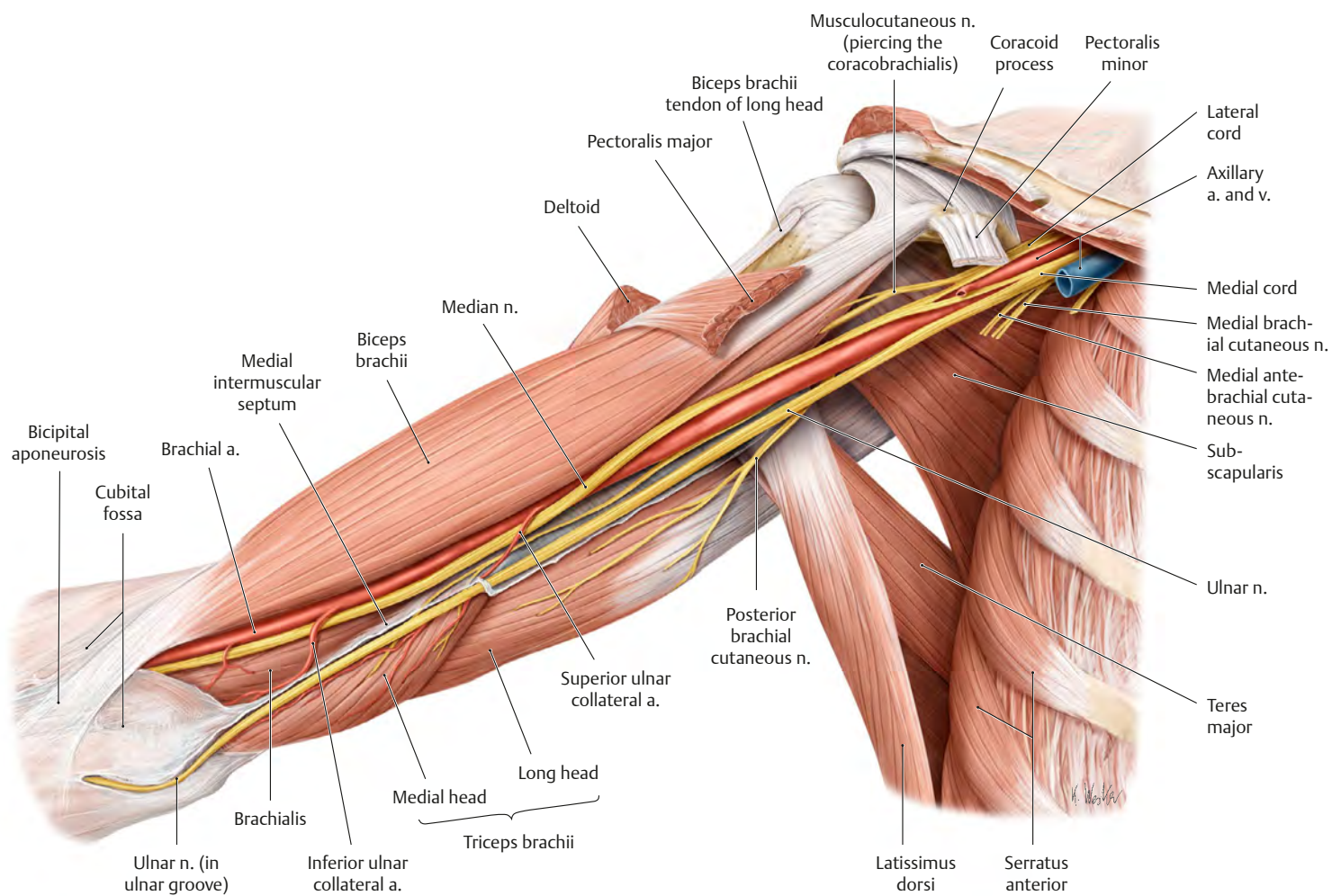
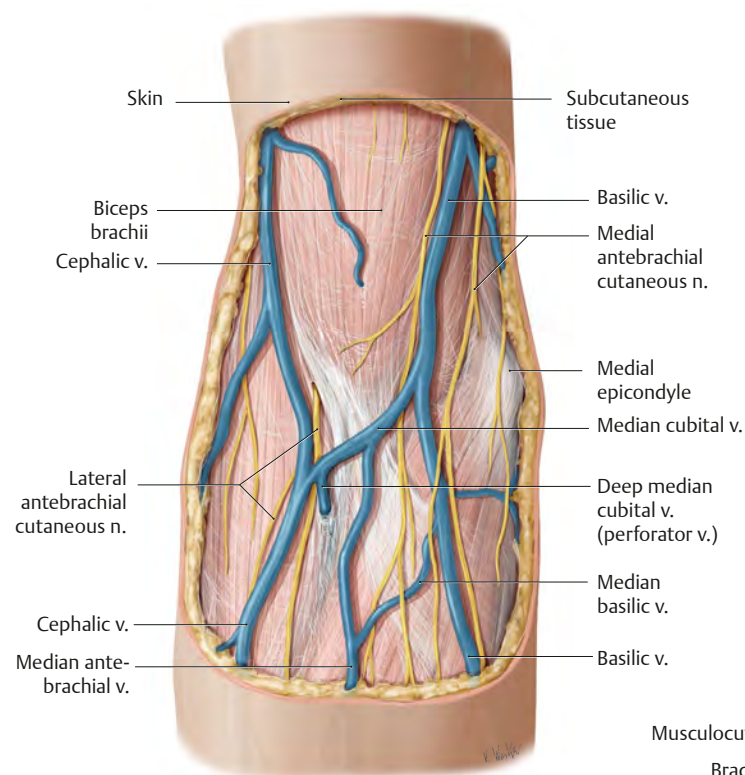
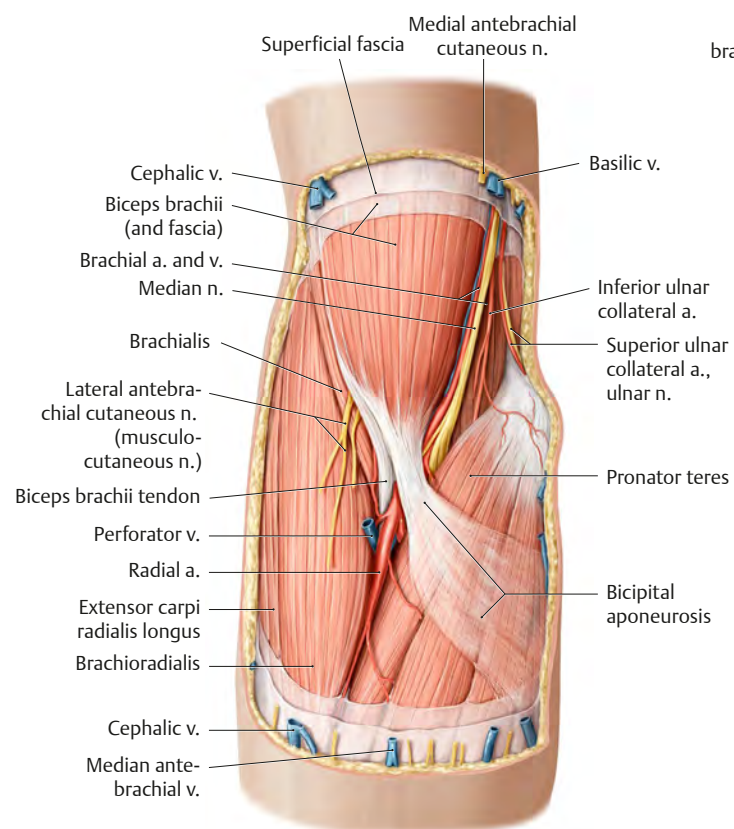
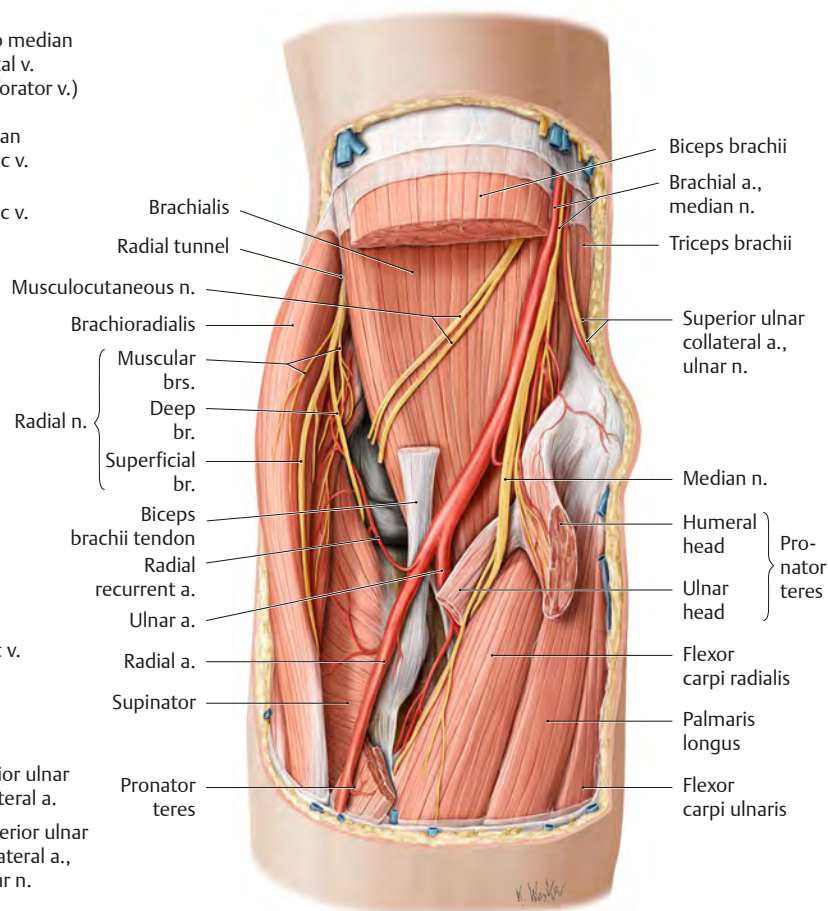


Fig. 28.36 Cubital region

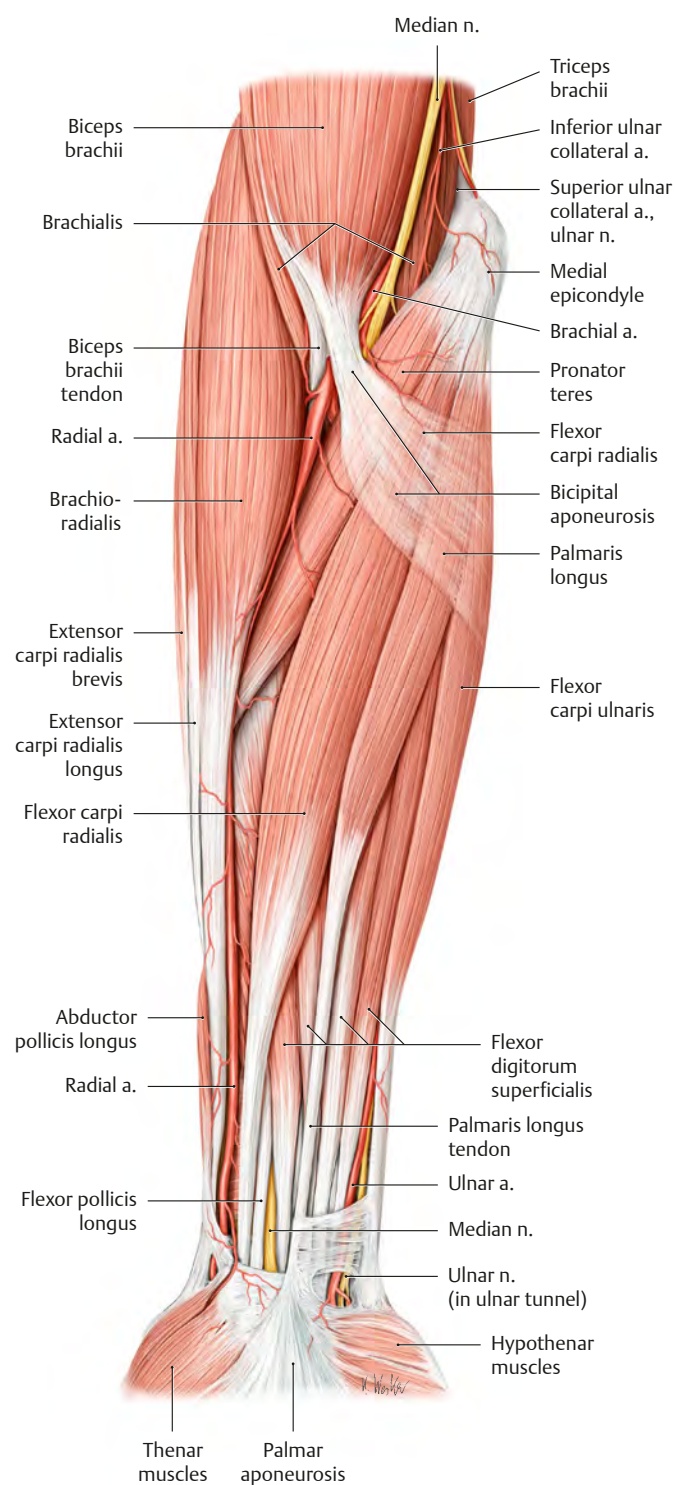
Right elbow, anterior view.

**A** Cutaneous neurovascular structures in the cubital fossa.**B** Superficial cubital fossa. *Removed:* Fasciae and epifascial neurovascular structures.**C** Deep cubital fossa. *Removed:* Biceps brachii (distal muscle belly). *Retracted:* Brachioradialis.

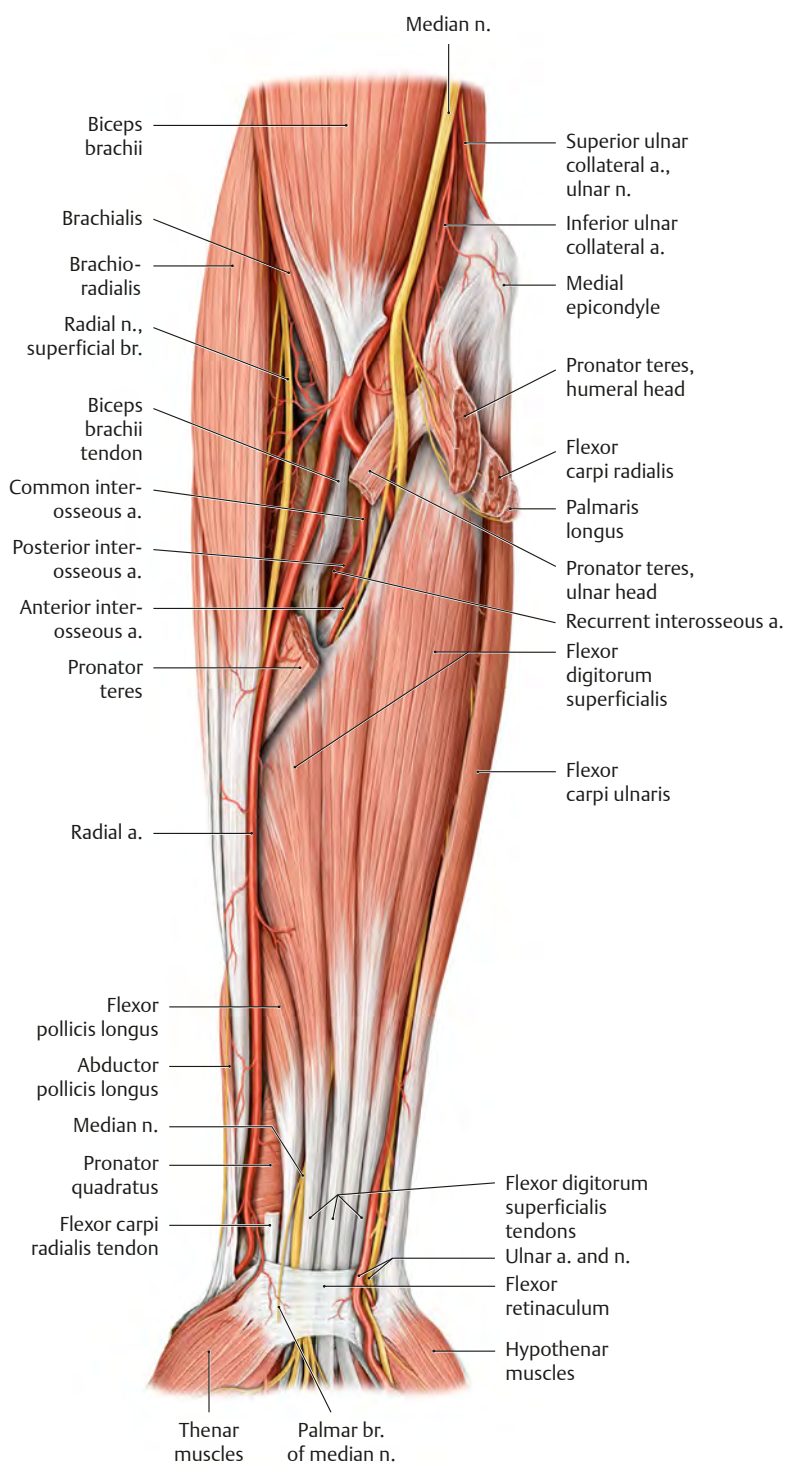
Anterior & Posterior Forearm

Fig. 28.37 Anterior forearm

Right forearm, anterior view.



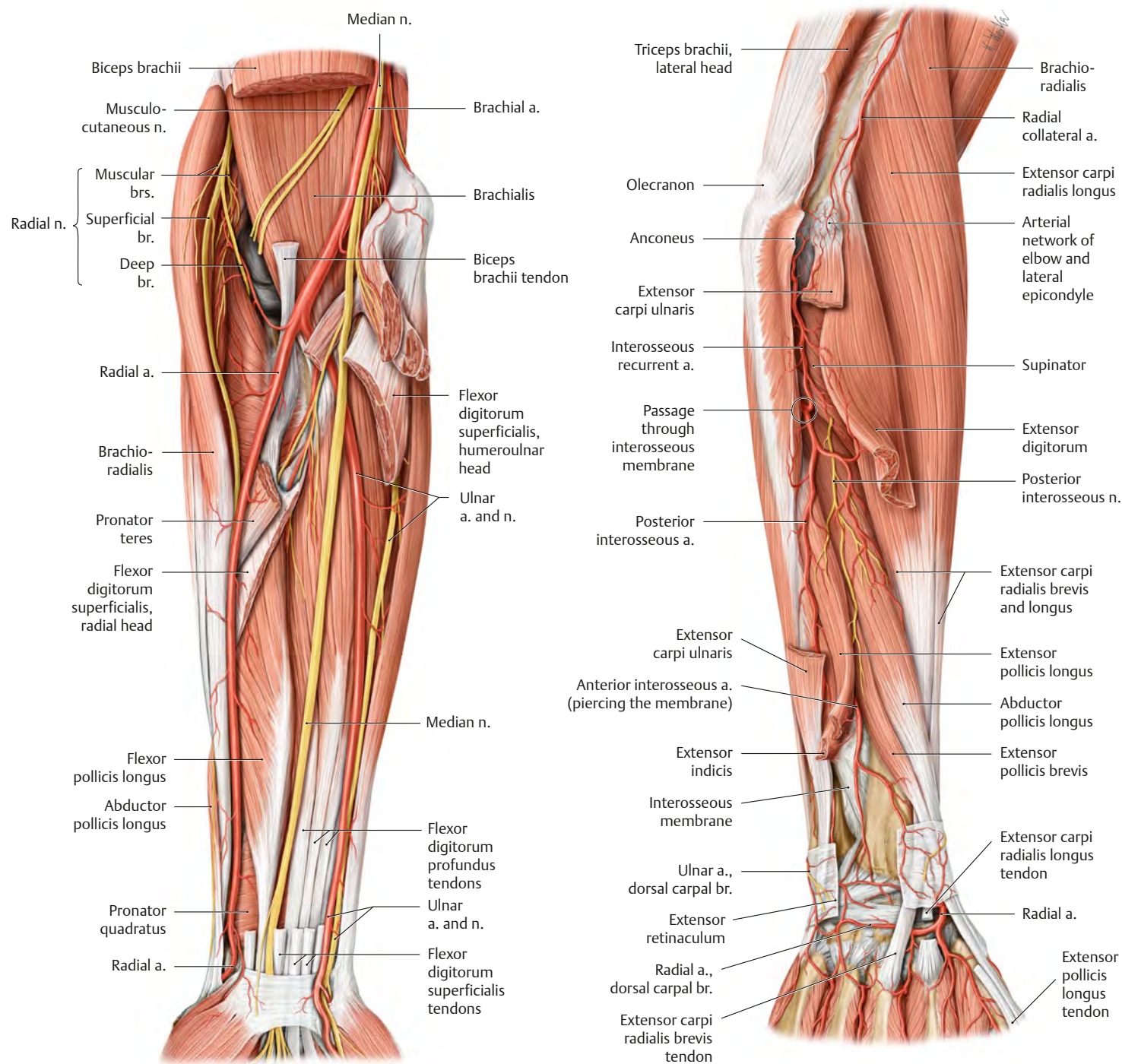
A Superficial layer. *Removed:* Fasciae and superficial neurovasculature.



B Middle layer. *Partially removed:* Superficial flexors (pronator teres, flexor digitorum superficialis, palmaris longus, and flexor carpi radialis).

Fig. 28.38 Posterior forearm

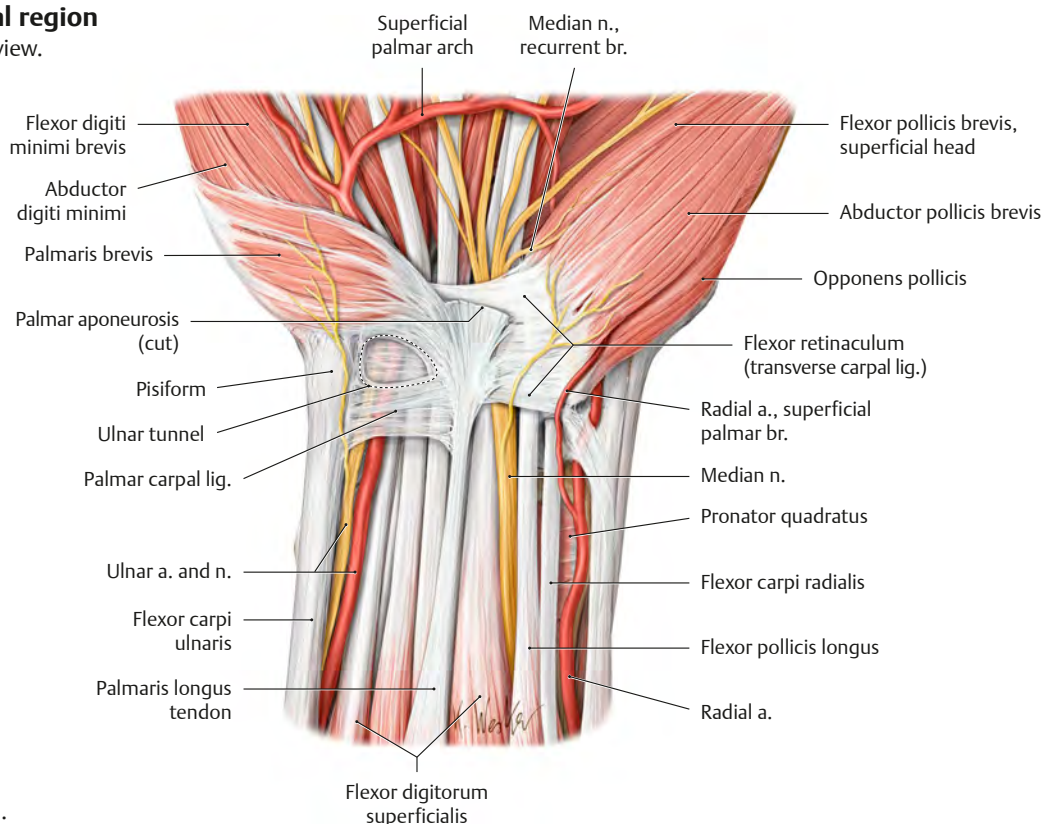
Right forearm, anterior view during pronation. *Reflected:* Anconeus and triceps brachii. *Removed:* Extensor carpi ulnaris and extensor digitorum.



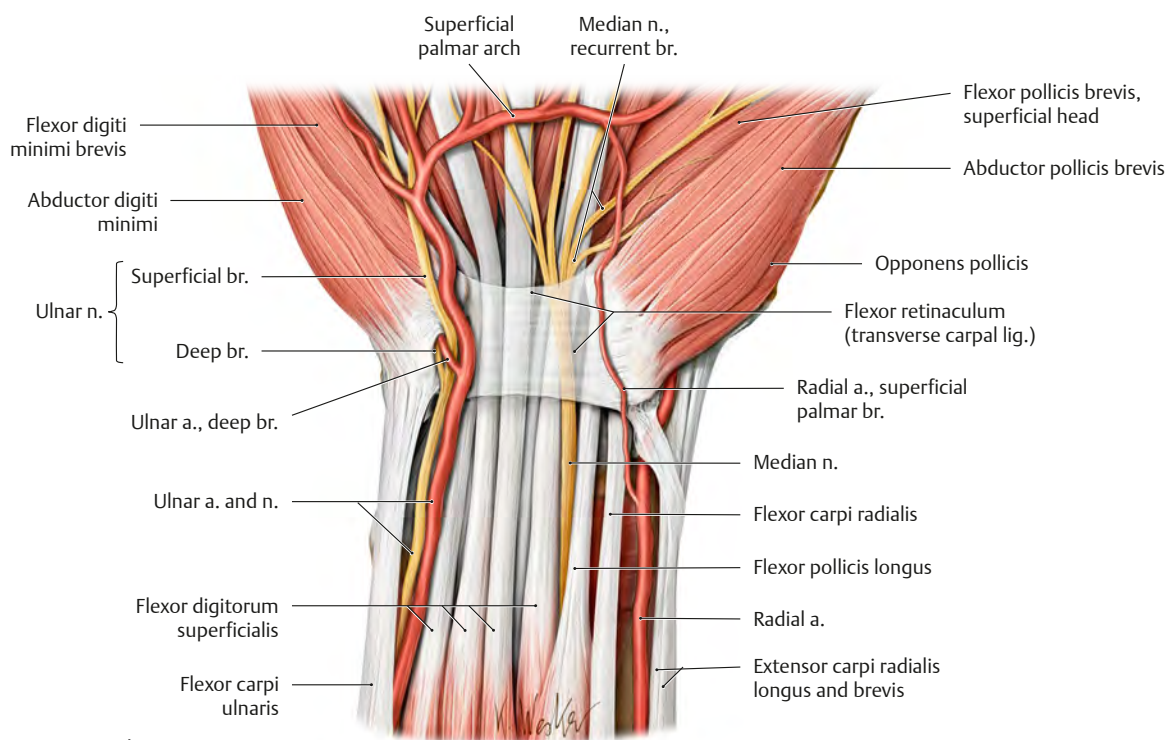
C Deep layer. *Removed:* Deep flexors.

Fig. 28.39 Anterior carpal region

Right hand, anterior (palmar) view.



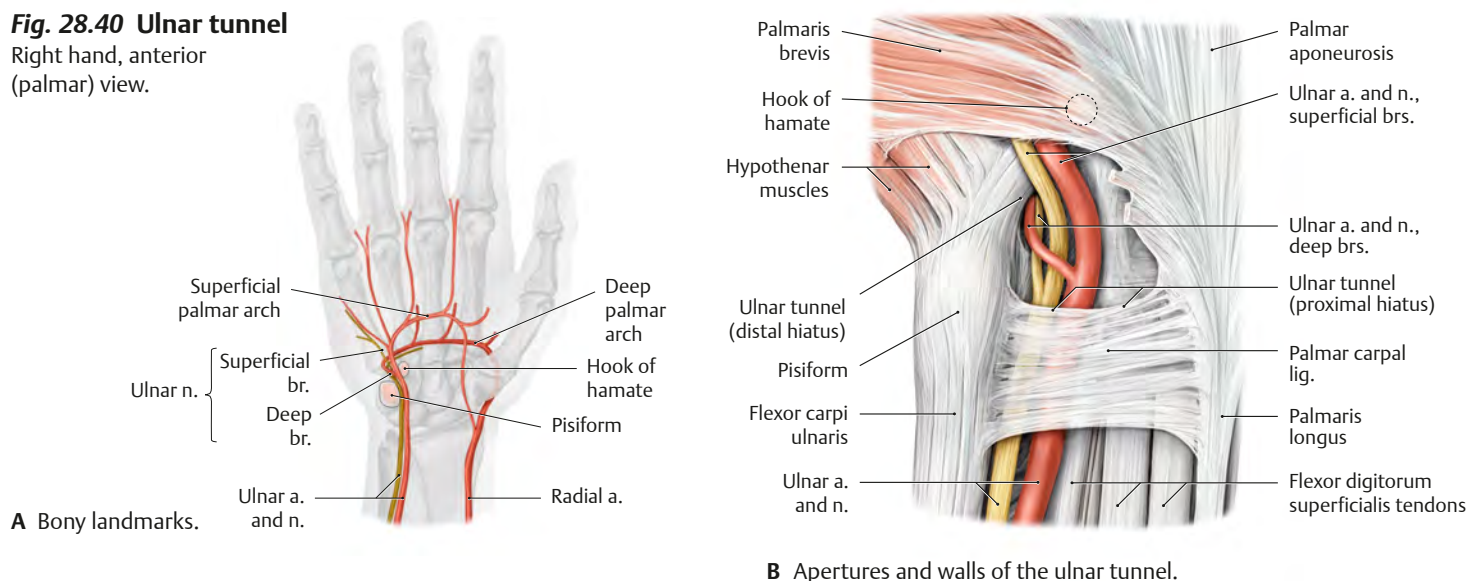
A Ulnar tunnel and deep palm.



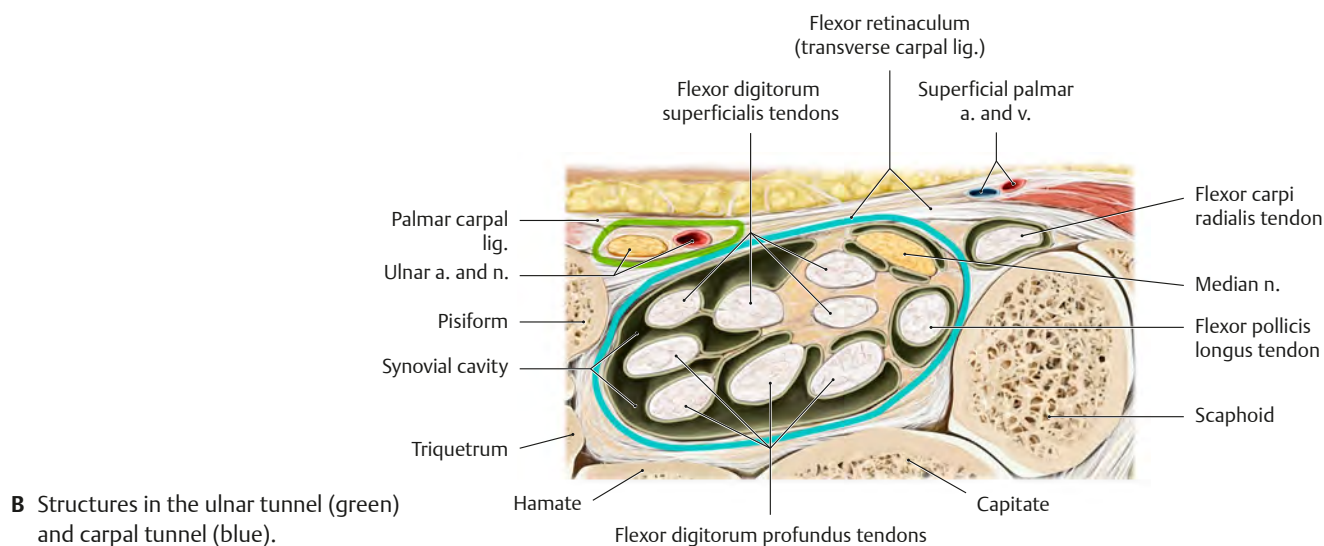
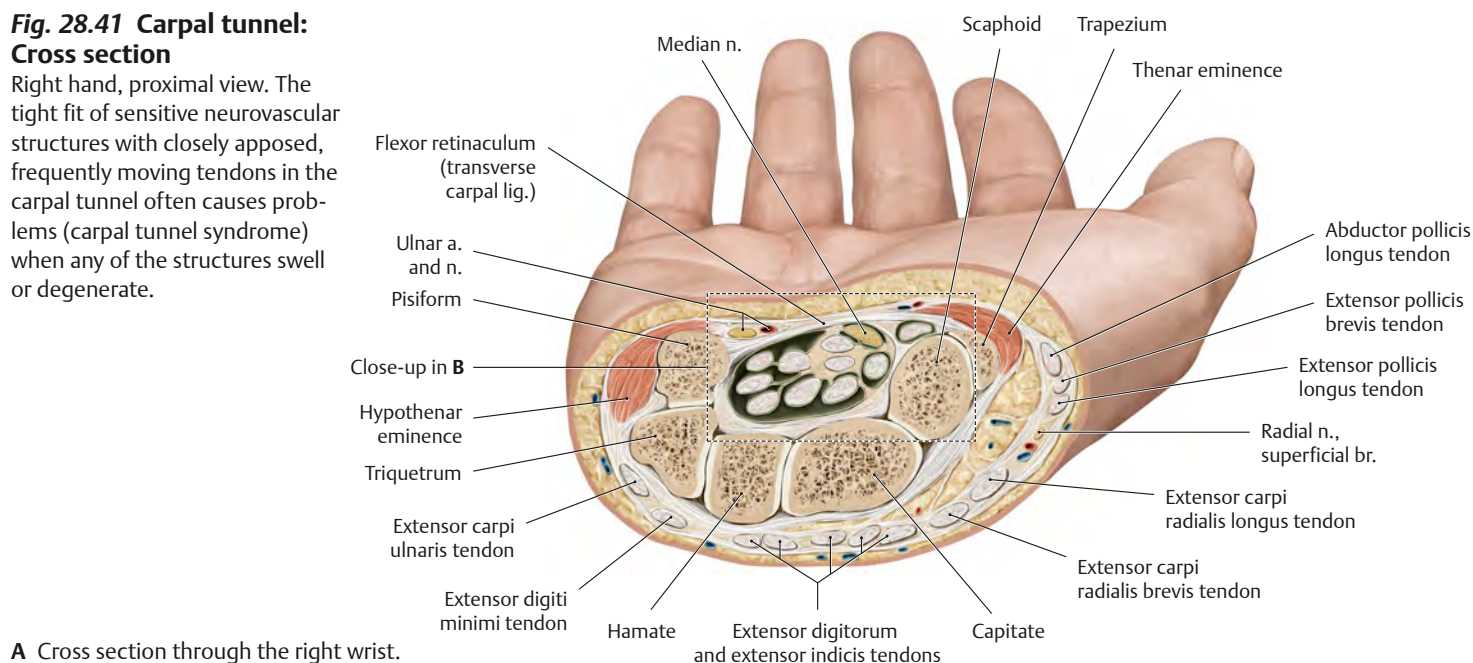
B Carpal tunnel with flexor retinaculum transparent. *Removed:* palmaris brevis, palmaris longus, palmar aponeurosis, and palmar carpal ligament.

Fig. 28.40 Ulnar tunnel

Right hand, anterior (palmar) view.

**Fig. 28.41 Carpal tunnel: Cross section**

Right hand, proximal view. The tight fit of sensitive neurovascular structures with closely apposed, frequently moving tendons in the carpal tunnel often causes problems (carpal tunnel syndrome) when any of the structures swell or degenerate.



Palm of the Hand

Fig. 28.42 Superficial neurovascular structures of the palm
Right hand, anterior view.

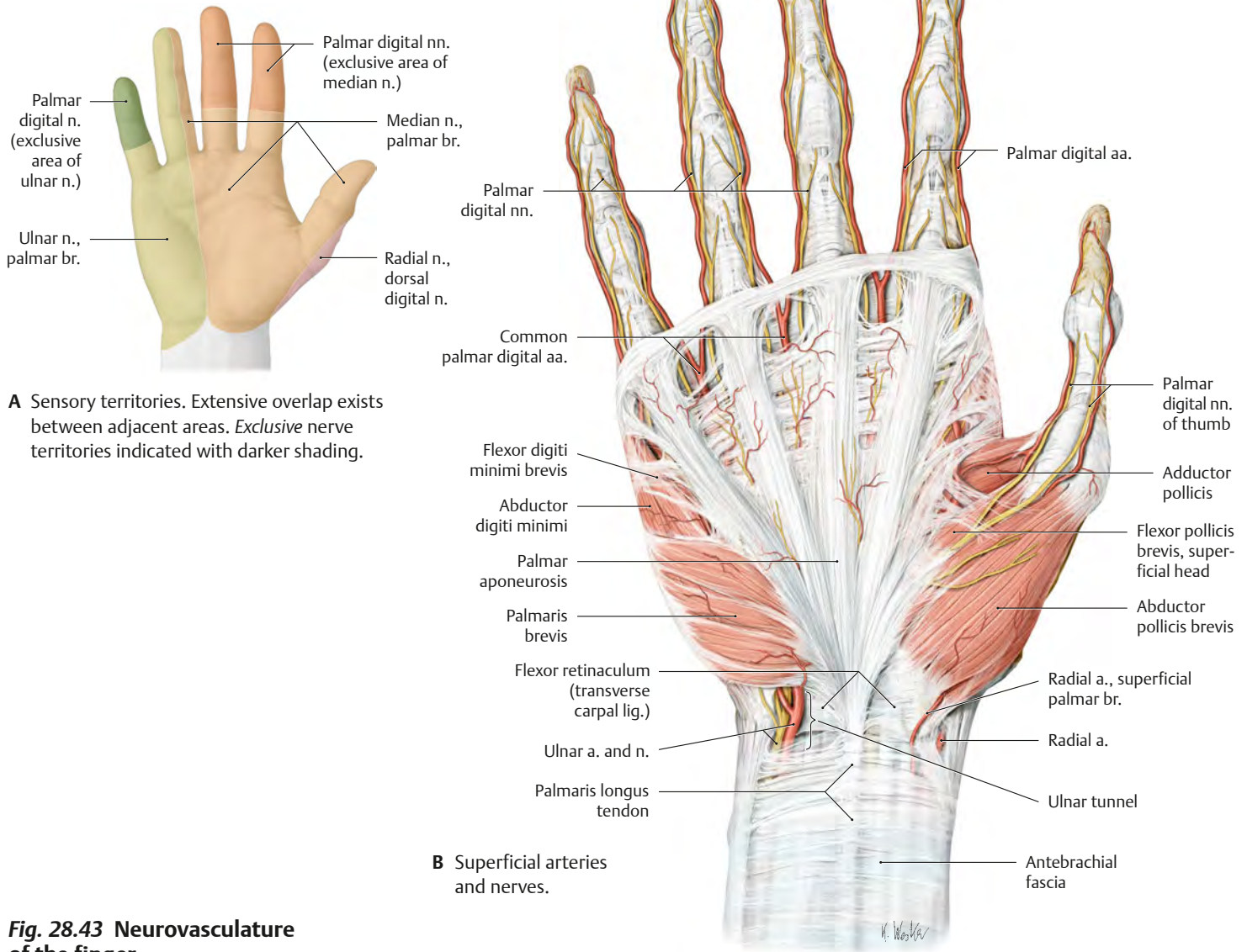


Fig. 28.43 Neurovasculature of the finger
Right middle finger, lateral view.

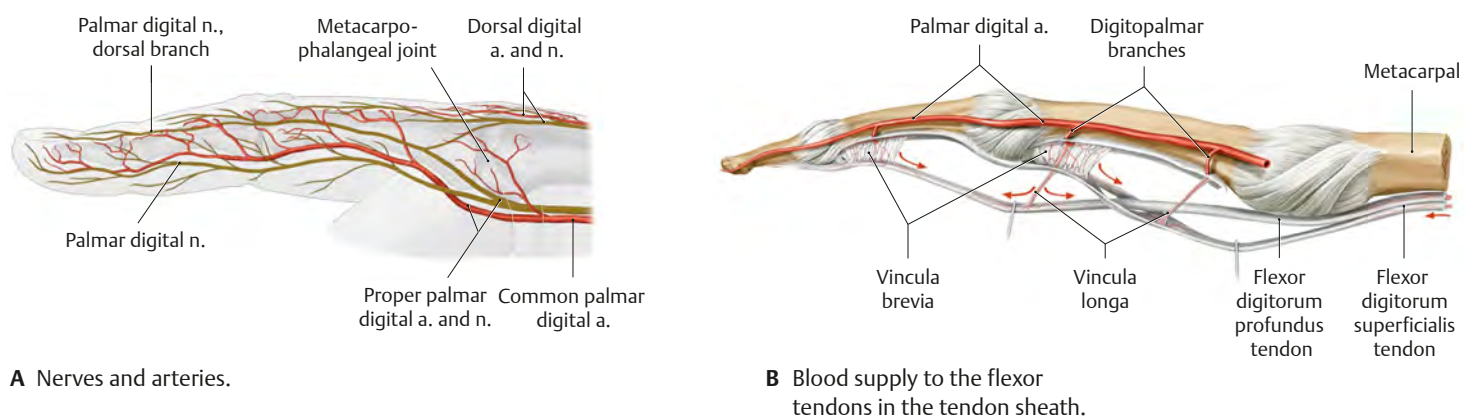
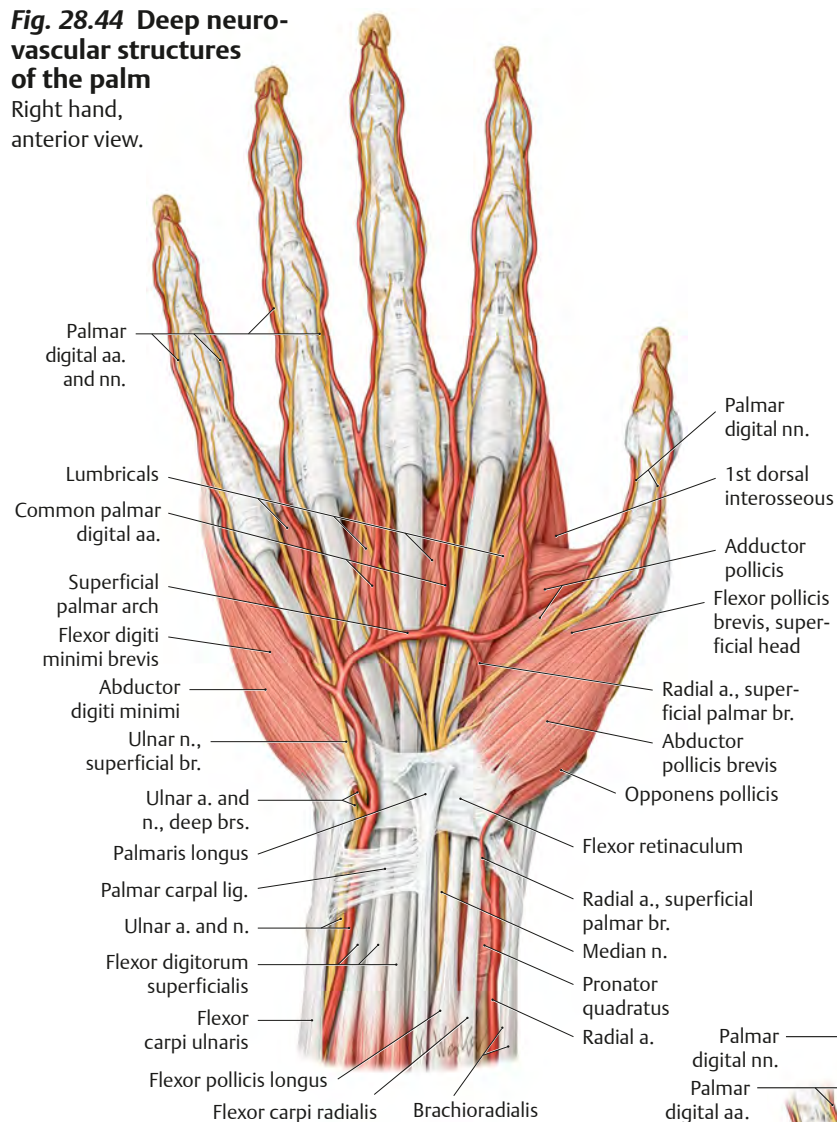


Fig. 28.44 Deep neuro-vascular structures of the palm

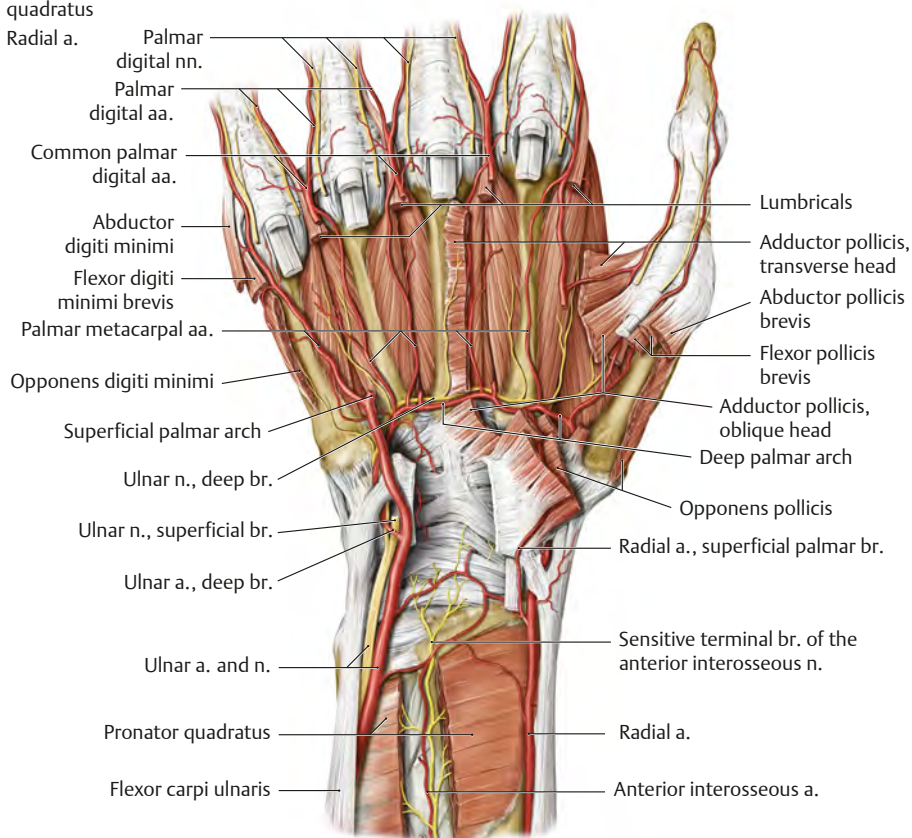
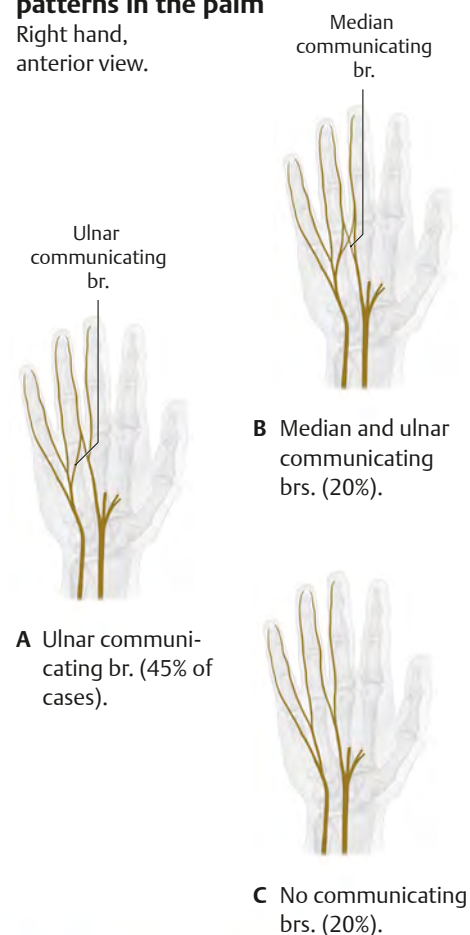
Right hand, anterior view.



A Superficial palmar arch.

Fig. 28.45 Innervation patterns in the palm

Right hand, anterior view.

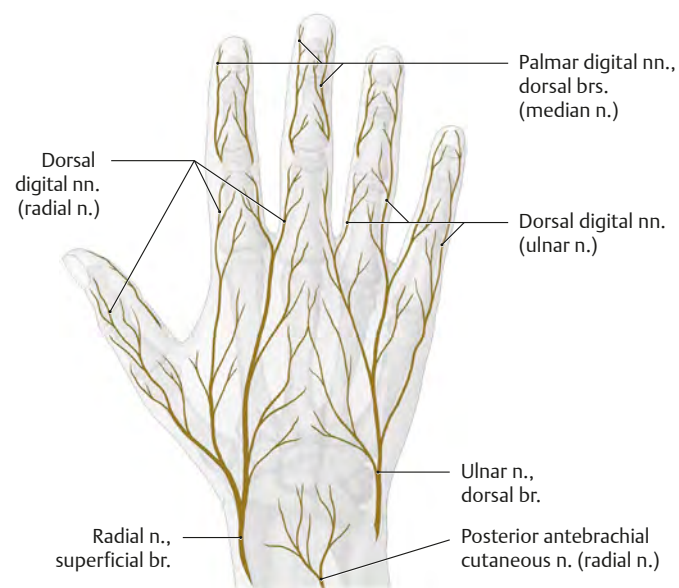


B Deep palmar arch.

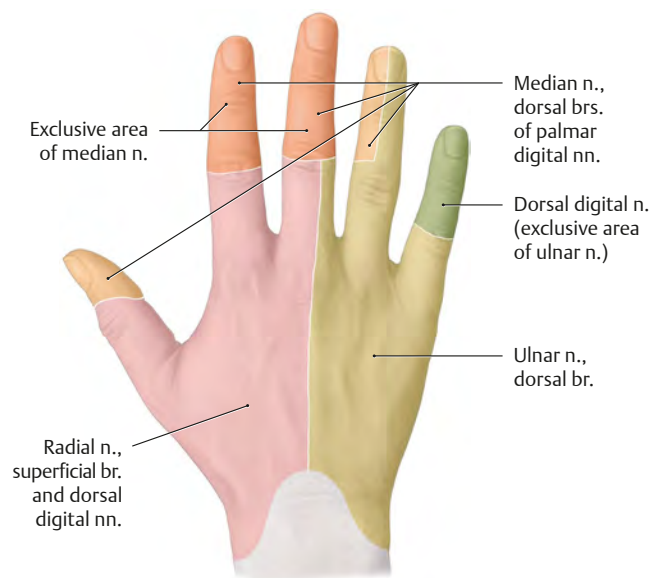
Dorsum of the Hand

Fig. 28.46 Cutaneous innervation of the dorsum of the hand

Right hand, posterior view.



A Nerves of the dorsum.



B Sensory territories. Extensive overlap exists between adjacent areas. Exclusive nerve territories indicated with darker shading.

Fig. 28.47 Anatomic snuffbox

Right hand, radial view. The three-sided “anatomic snuffbox” (shaded green) is bounded by the tendons of insertion of the abductor pollicis longus and extensors pollicis brevis and longus.

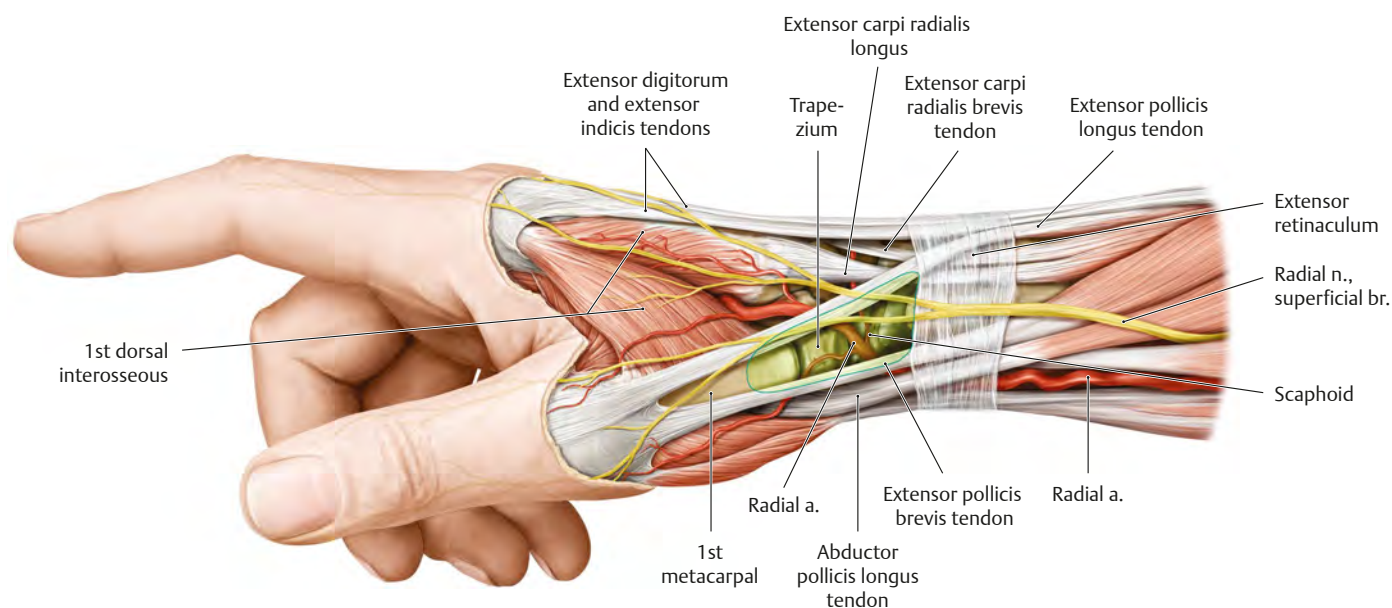
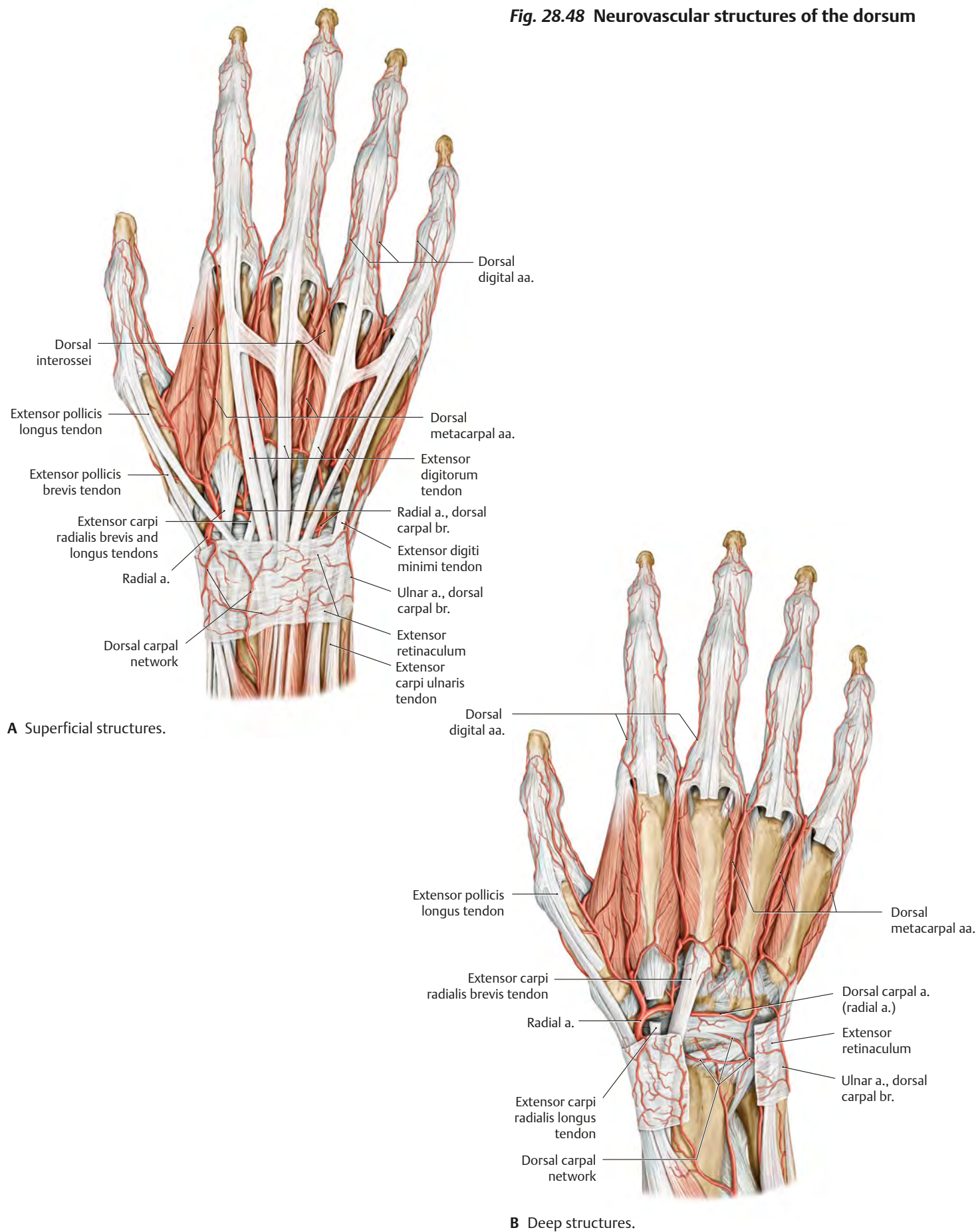


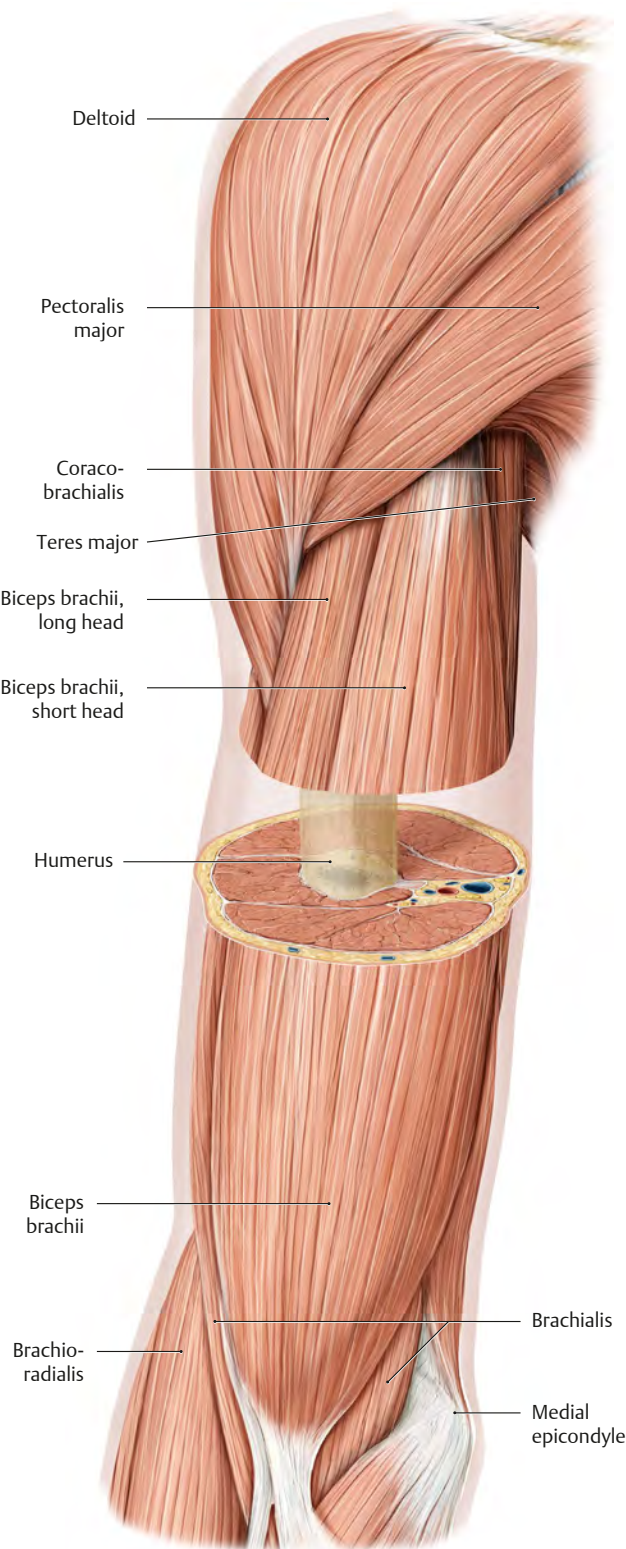
Fig. 28.48 Neurovascular structures of the dorsum



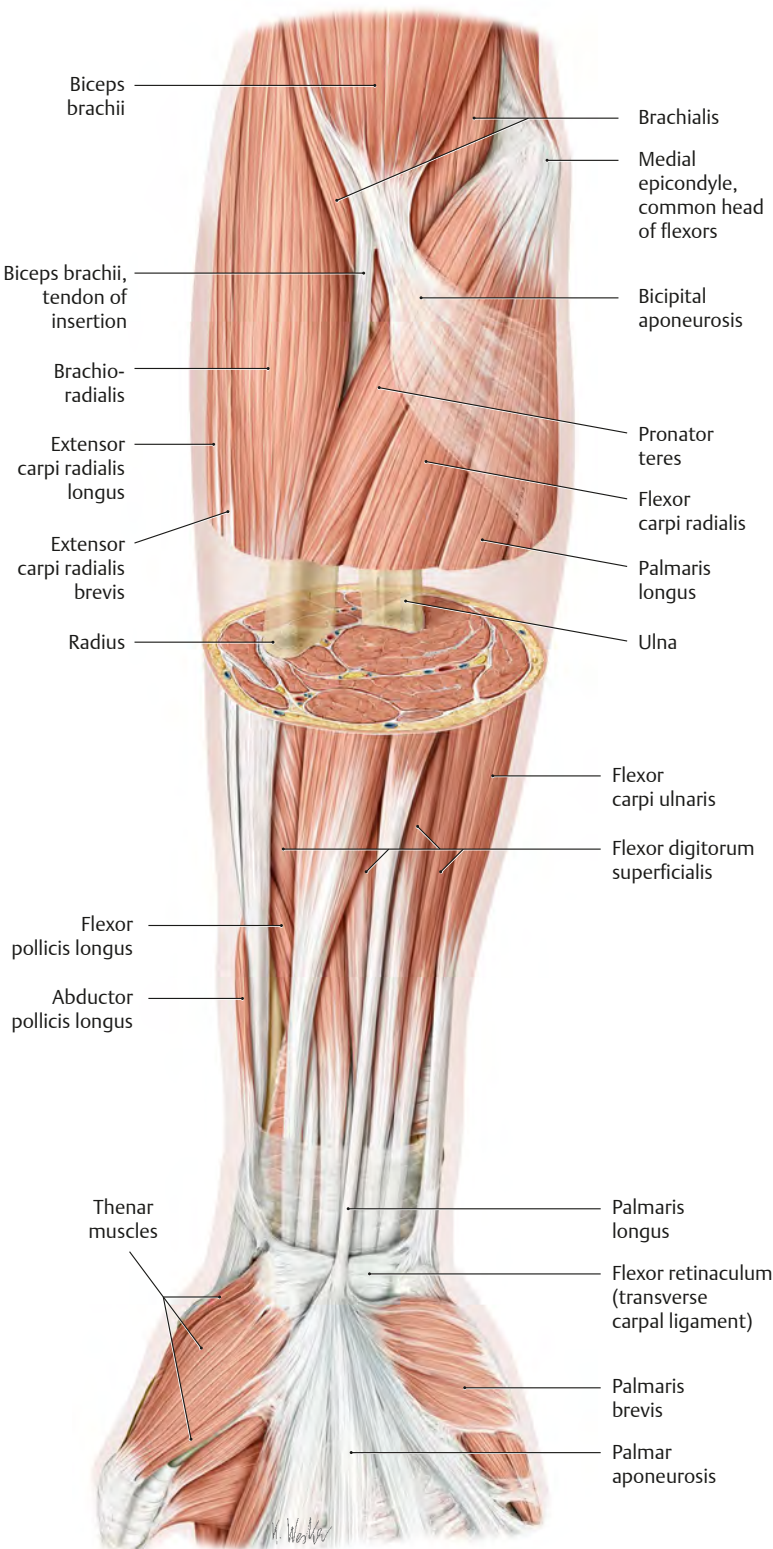
29 Sectional & Radiographic Anatomy

Sectional Anatomy of the Upper Limb

Fig. 29.1 Windowed dissection of the arm and forearm
Right limb, anterior view.



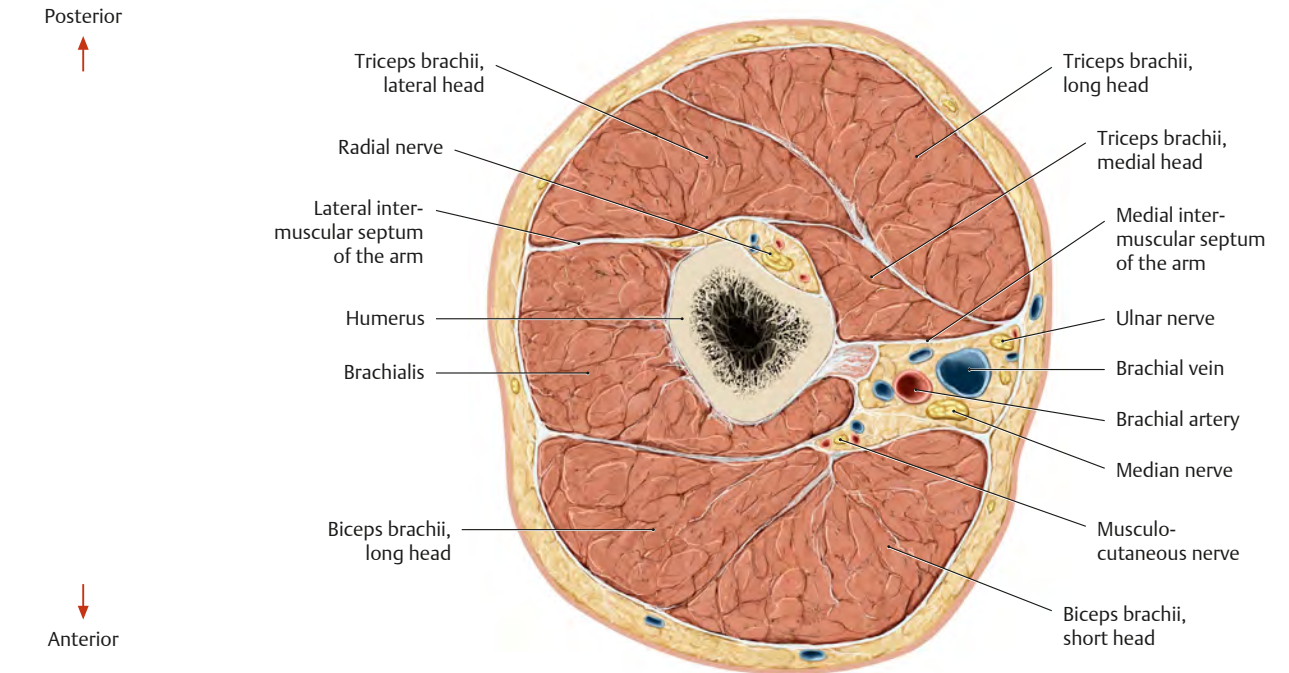
A Dissection of the arm.



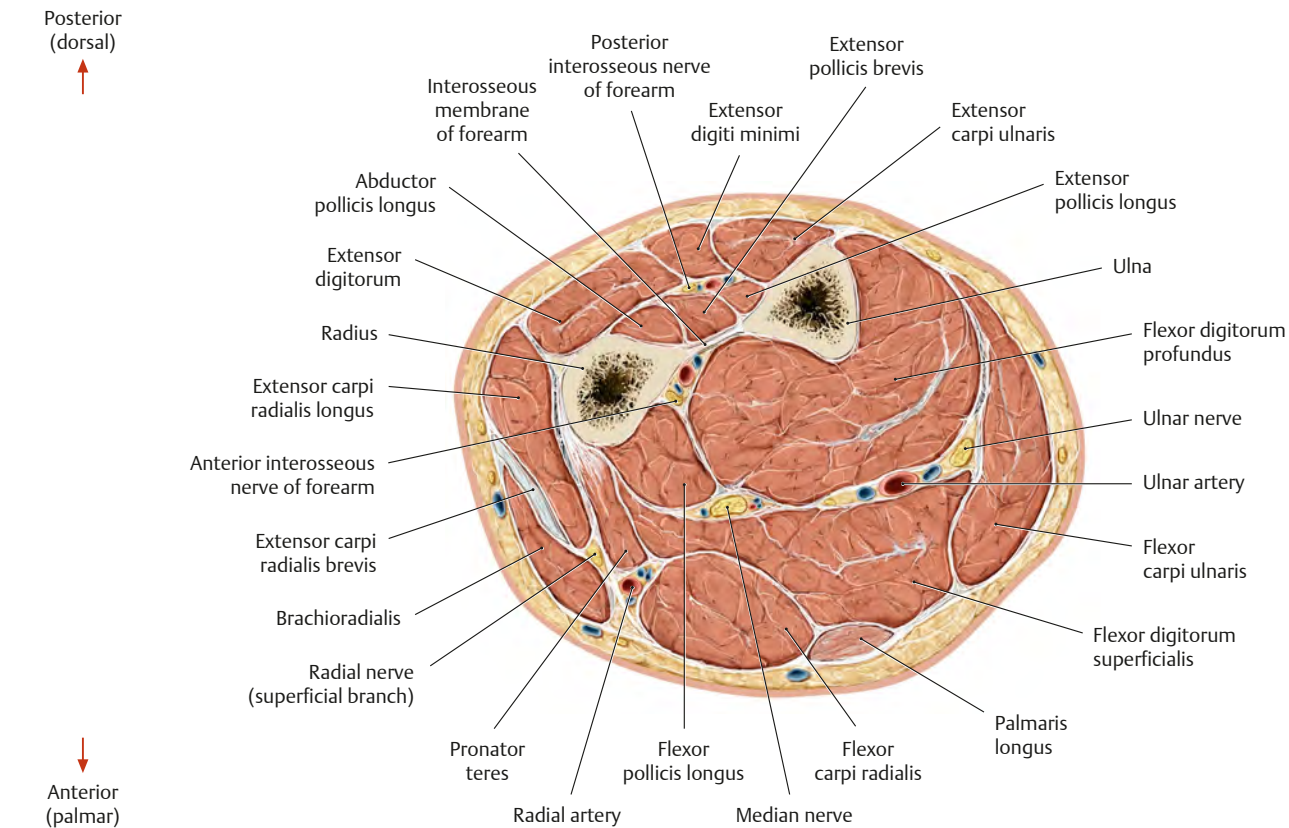
B Right forearm

Fig. 29.2 Cross-section through the arm and forearm

Right limb, proximal view.



A Arm (plane of section in Fig. 29.1A)

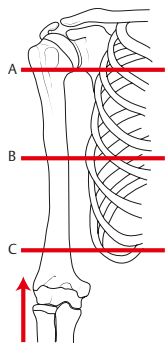


B Forearm (plane of section in Fig. 29.1B)

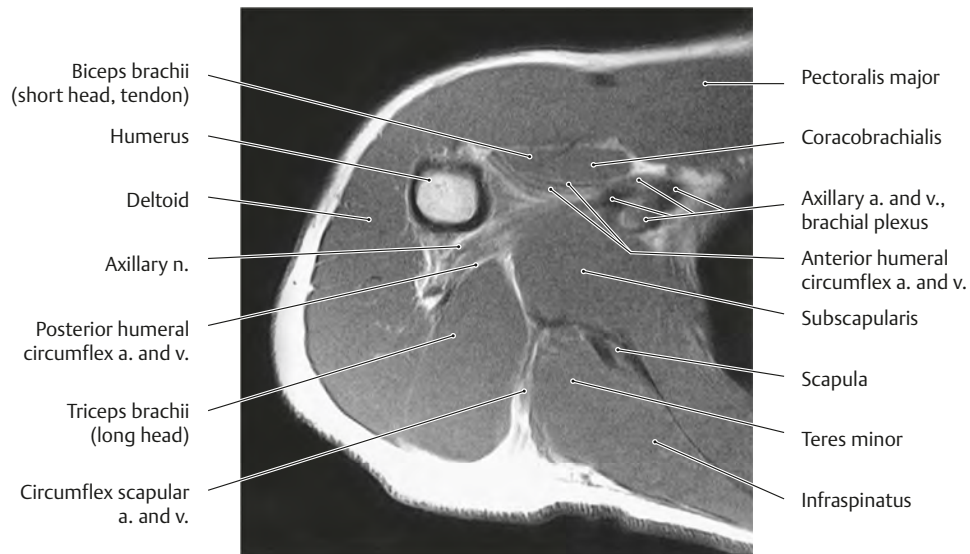
Radiographic Anatomy of the Upper Limb (I)

Upper Limb

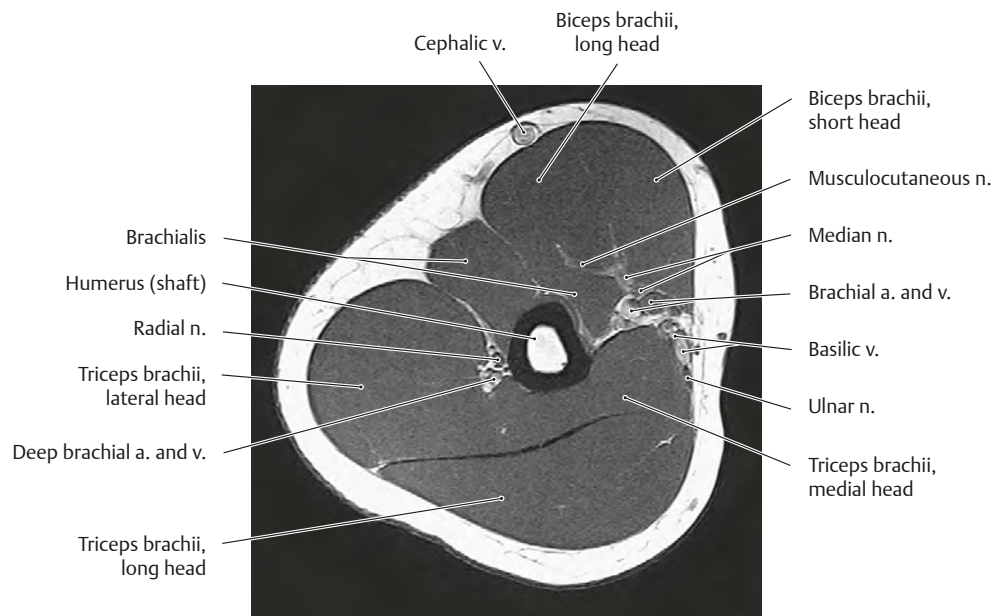
Fig. 29.3 MRI of the arm
Transverse section, distal (inferior) view.



A Proximal arm. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)



B Mid-arm. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)



C Distal arm. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

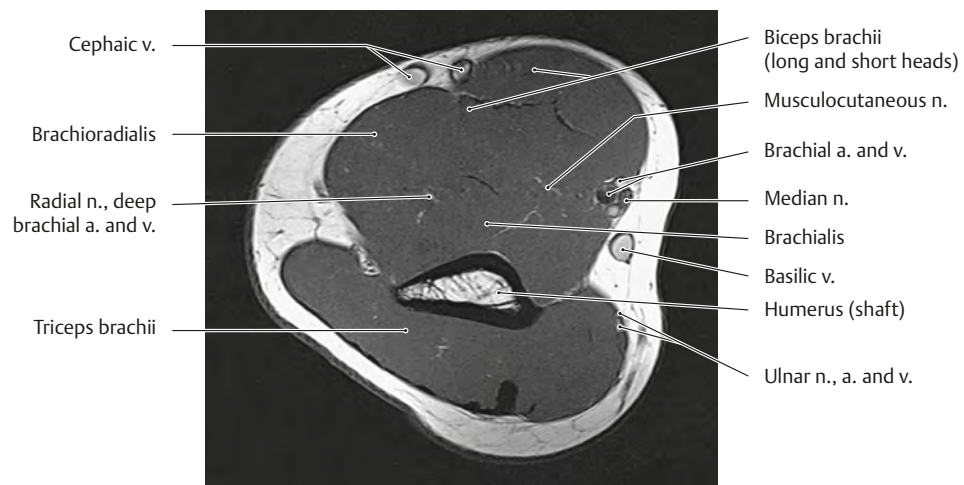
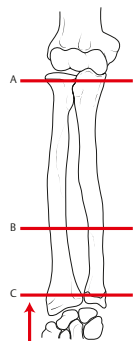


Fig. 29.4 MRI of the forearm

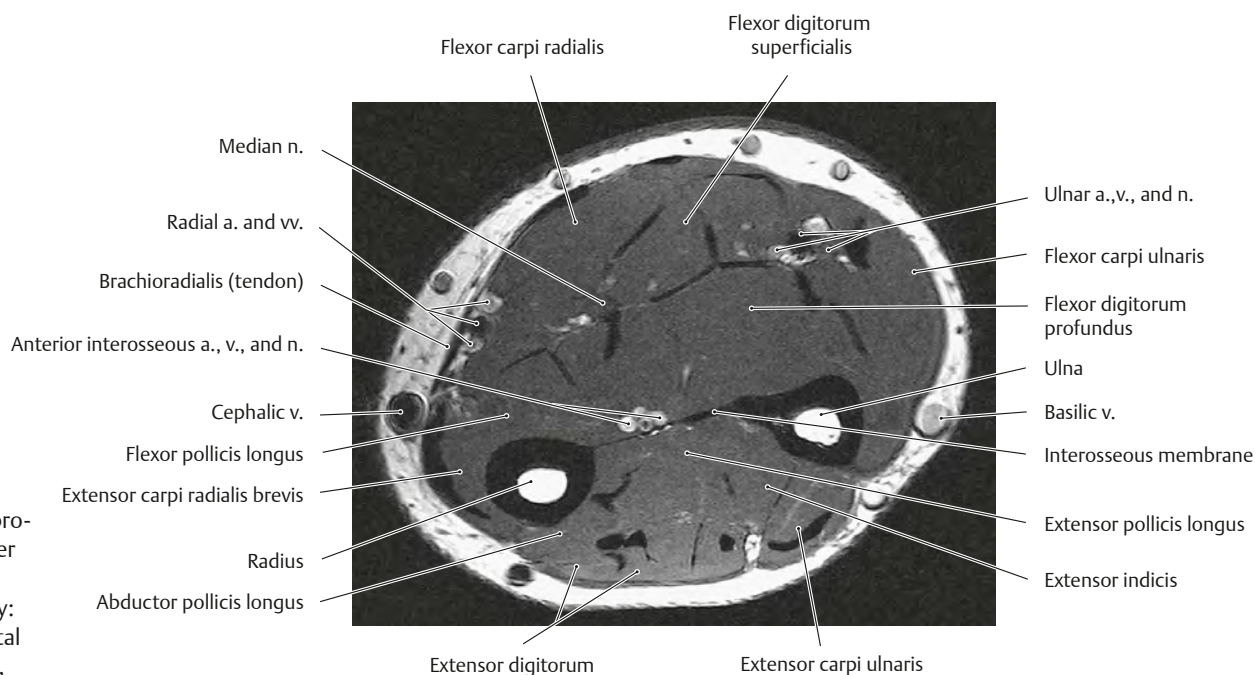
Transverse section, distal view.



A Proximal forearm. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)



B Mid-forearm. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)



C Distal forearm. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)



Radiographic Anatomy of the Upper Limb (II)

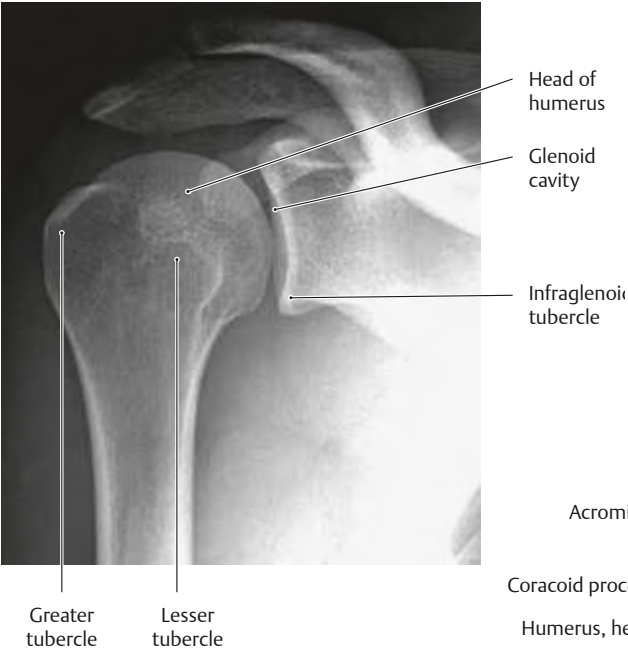


Fig. 29.5 Radiograph of the right shoulder
Anteroposterior view.

Fig. 29.6 Radiograph of the scapula
Anteroposterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

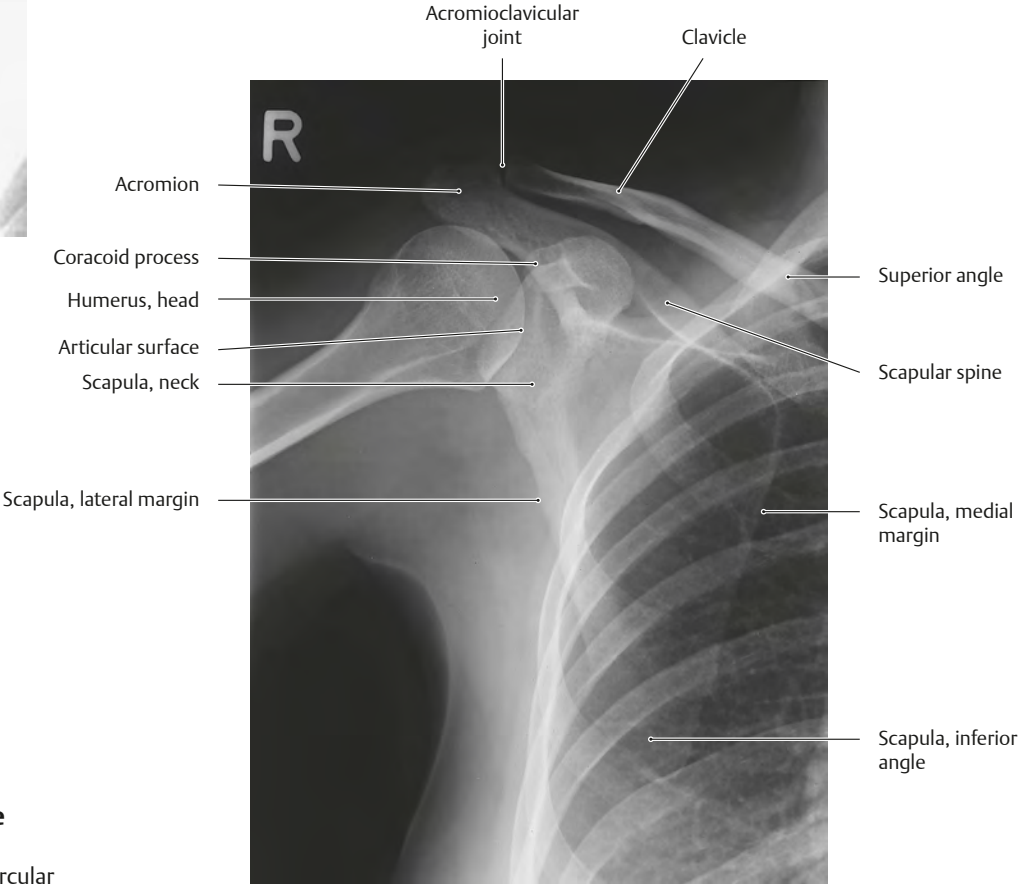
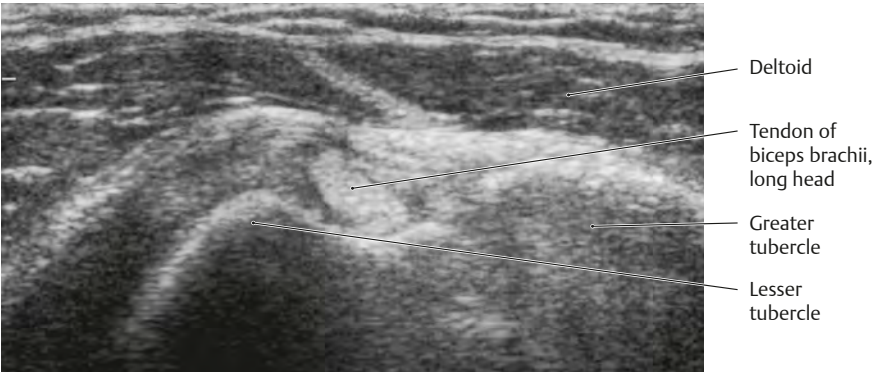
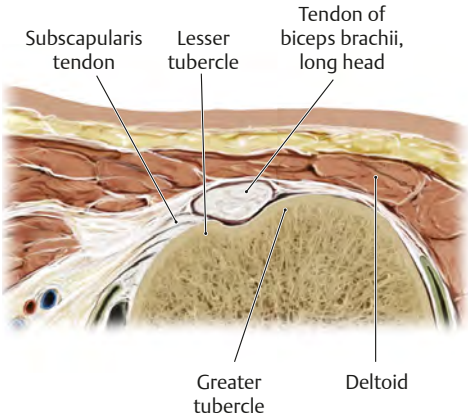


Fig. 29.7 Diagnostic ultrasound of the anterior region of the left shoulder
Transverse section at the level of the intertubercular groove. (Reproduced from Konerman W, Gruber G. Ultraschalldiagnostik der Bewegungsorgane, 2nd ed. Stuttgart: Thieme; 2006.)

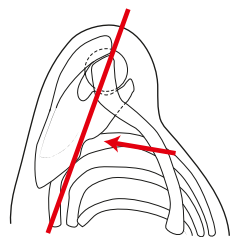


A Sonogram.

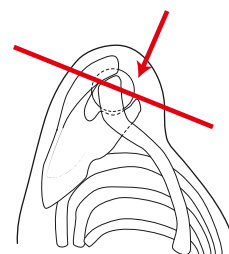
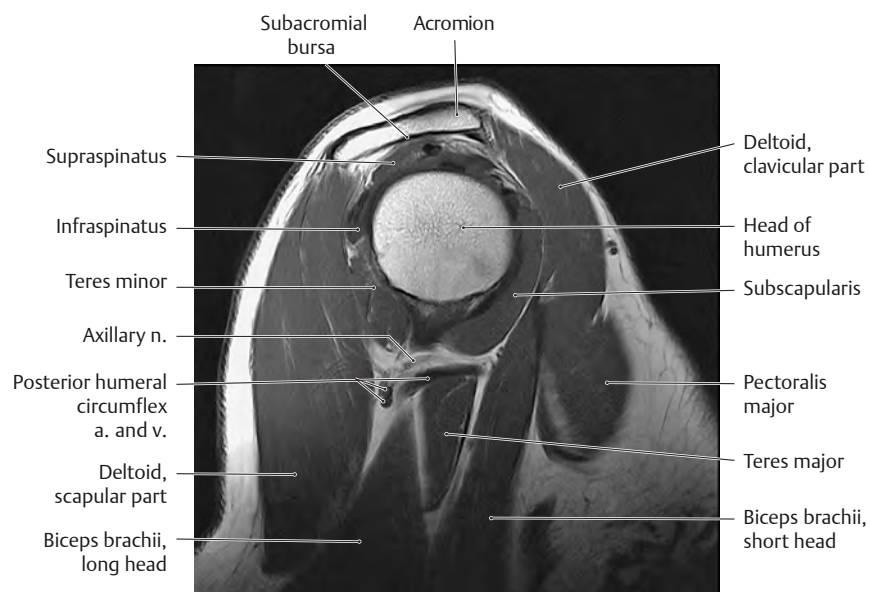
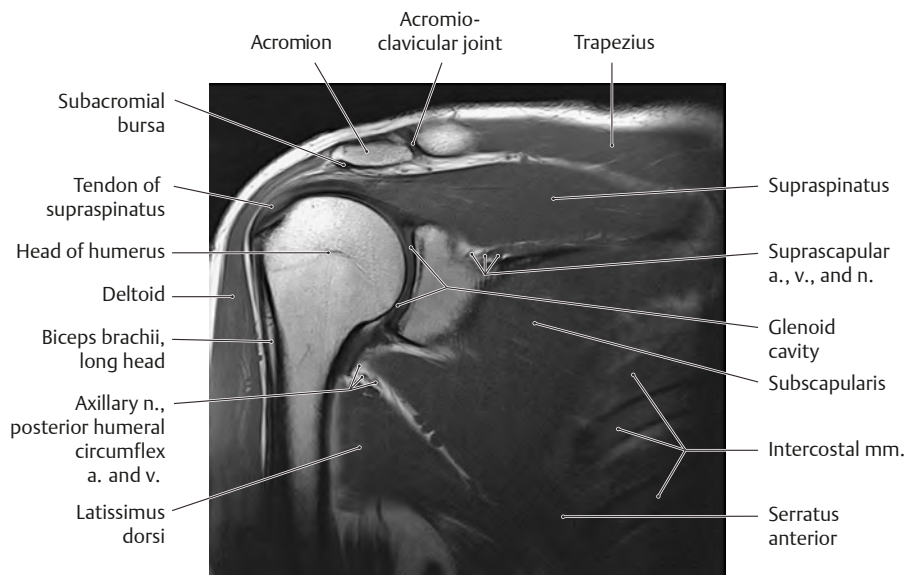


B Schematic of the transverse section.

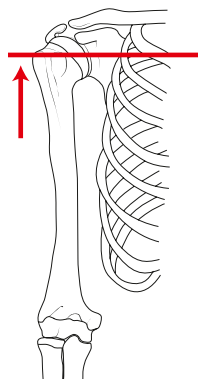
Fig. 29.8 MRI of the right shoulder joint in three planes



A Coronal section, anterior view.



B Sagittal section, lateral view.



C Transverse section, inferior view.

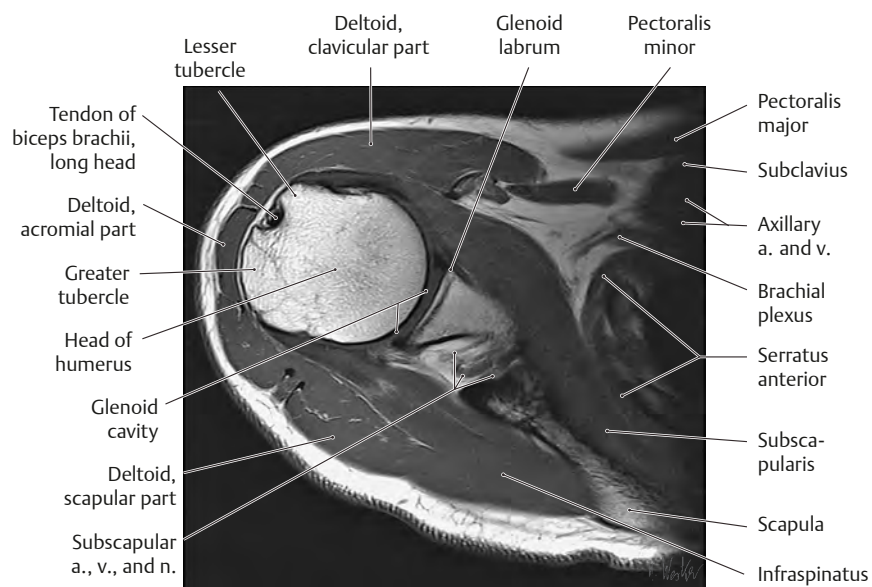


Fig. 29.9 Radiograph of the elbow

Anteroposterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

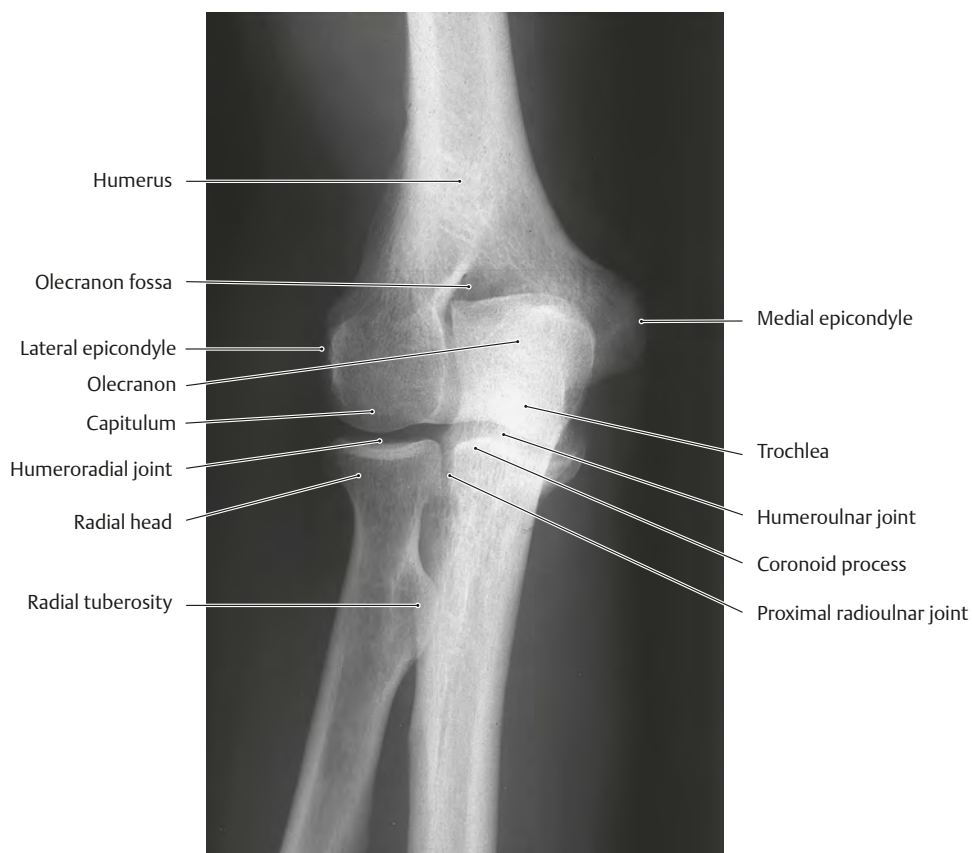


Fig. 29.10 Radiograph of the elbow

Lateral view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

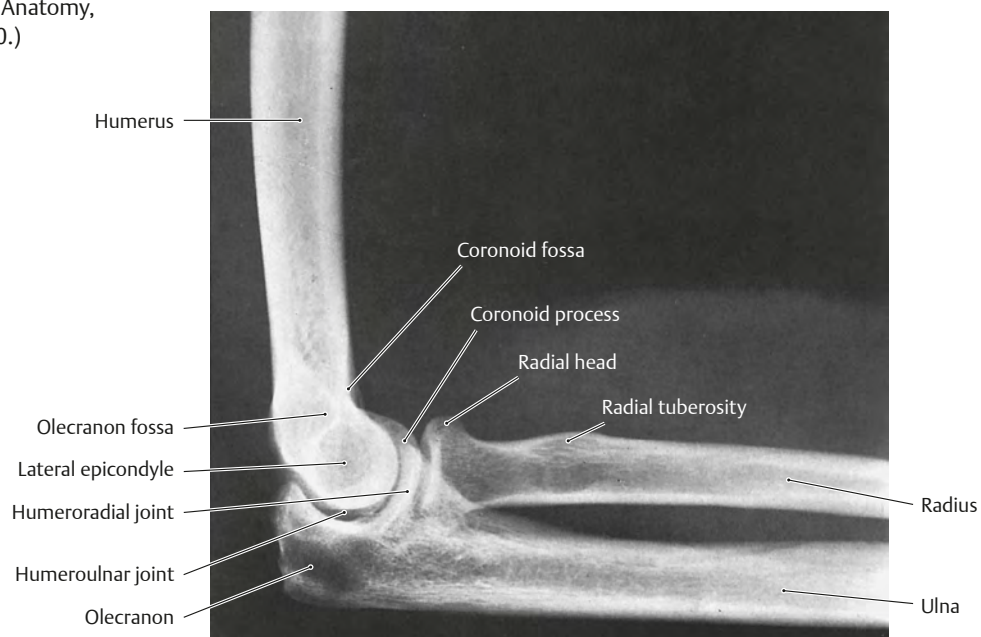
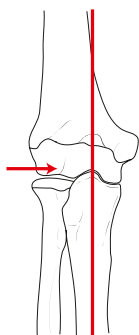
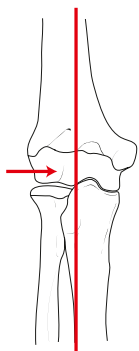


Fig. 29.11 MRI of the elbow

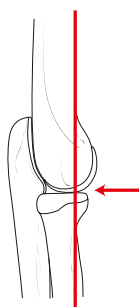
(Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)



A Sagittal section through the humeroulnar joint.



B Sagittal section through the humeroulnar and humeroradial joints.



C Coronal section through the humeroulnar and humeroradial joints.

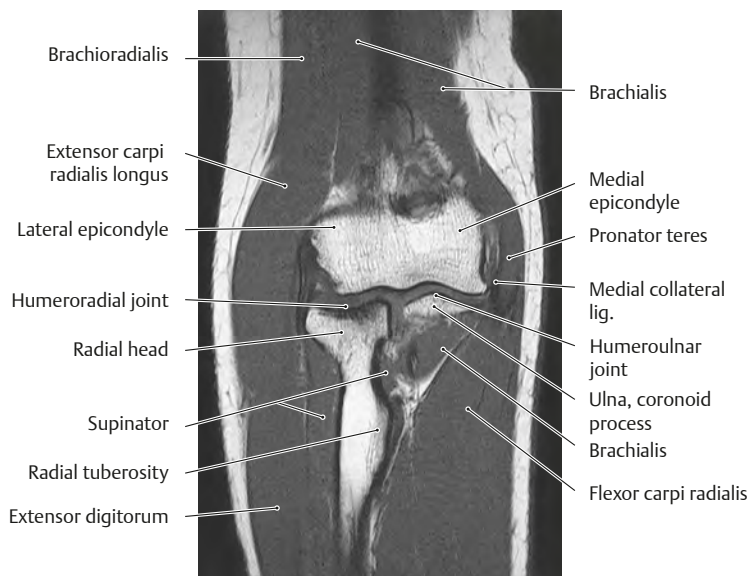
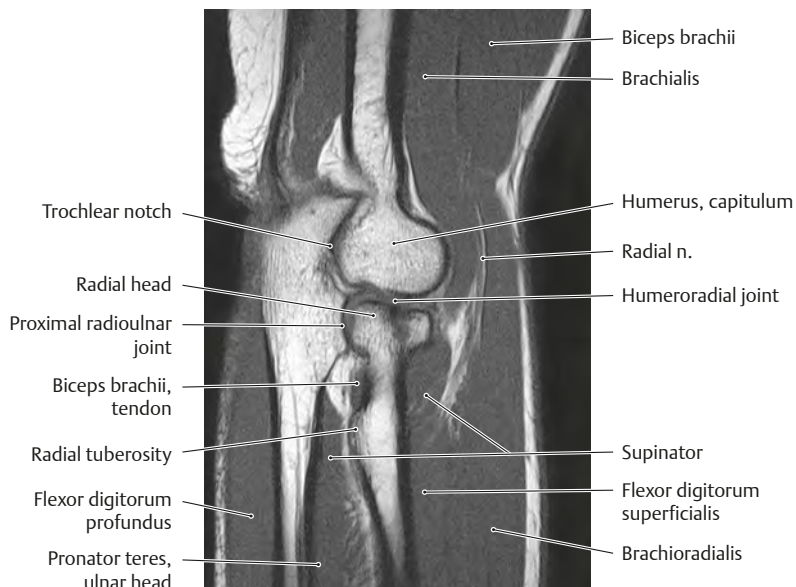
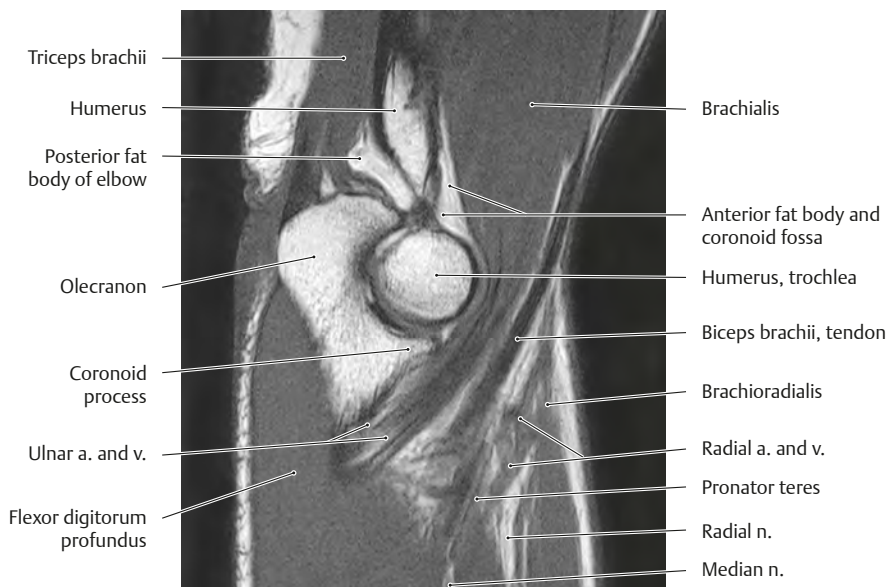


Fig. 29.12 Radiograph of the hand

(Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)



A Anteroposterior view.



B Oblique view.

Fig. 29.13 MRI of the right wrist

Transverse section, distal view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

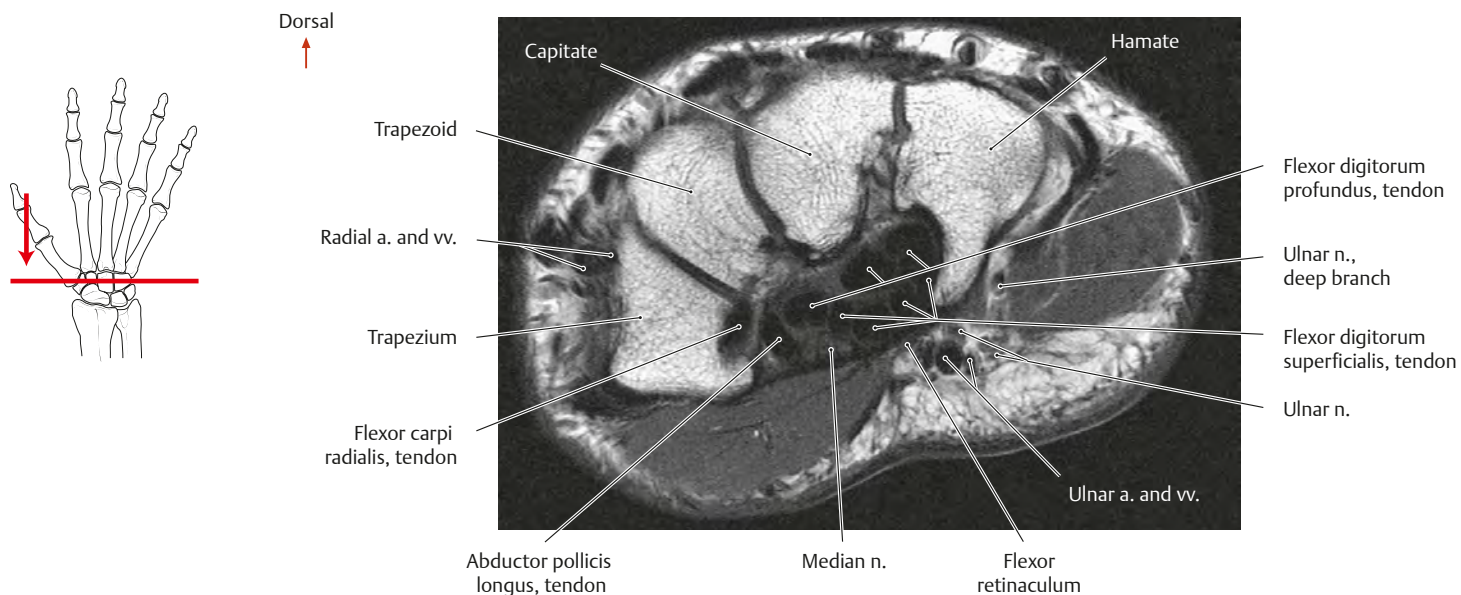
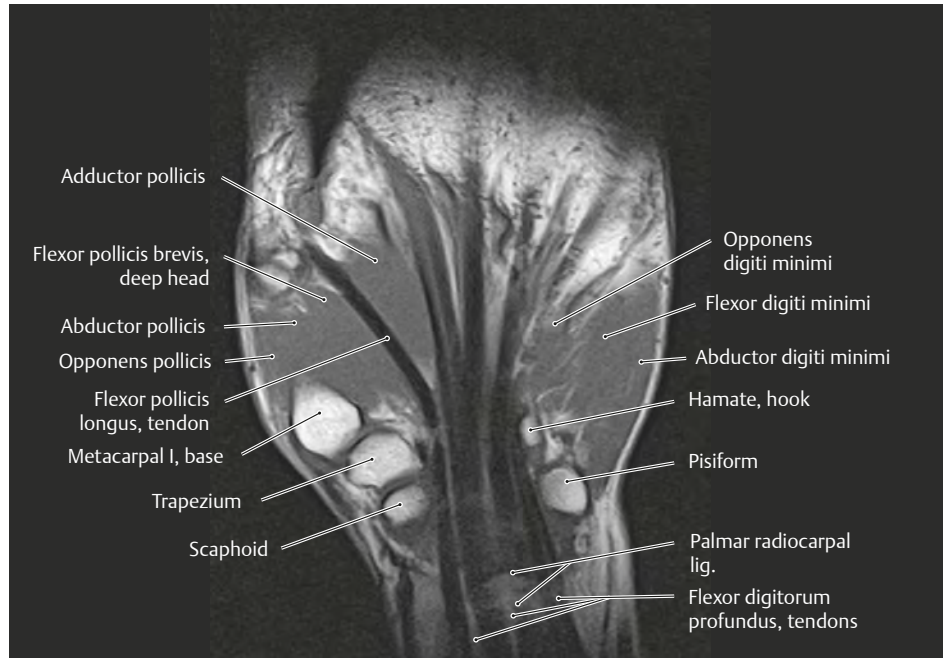
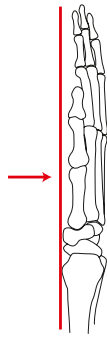
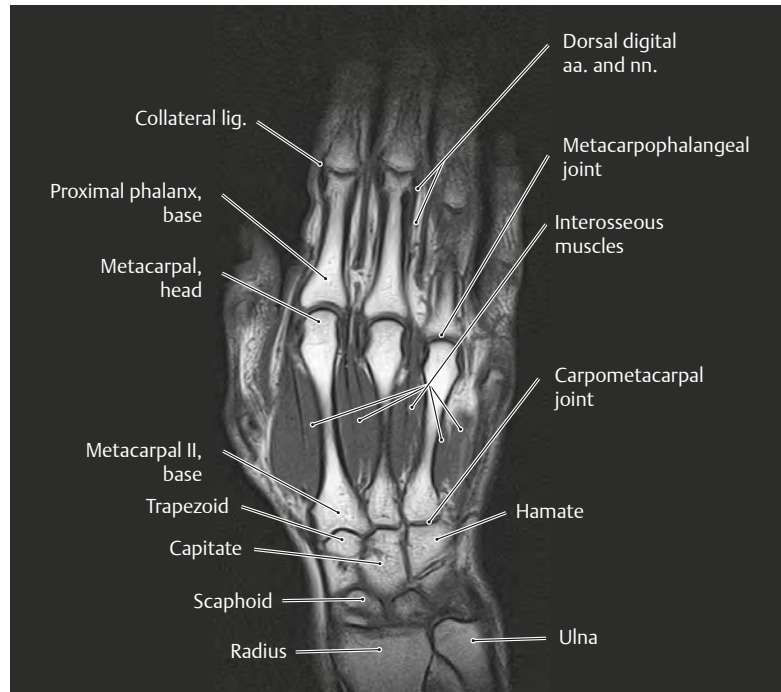
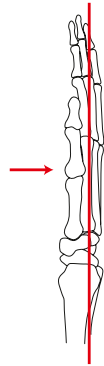


Fig. 29.14 MRI of the hand

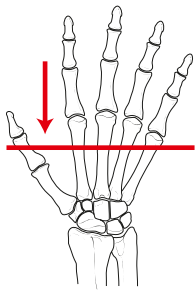
(Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)



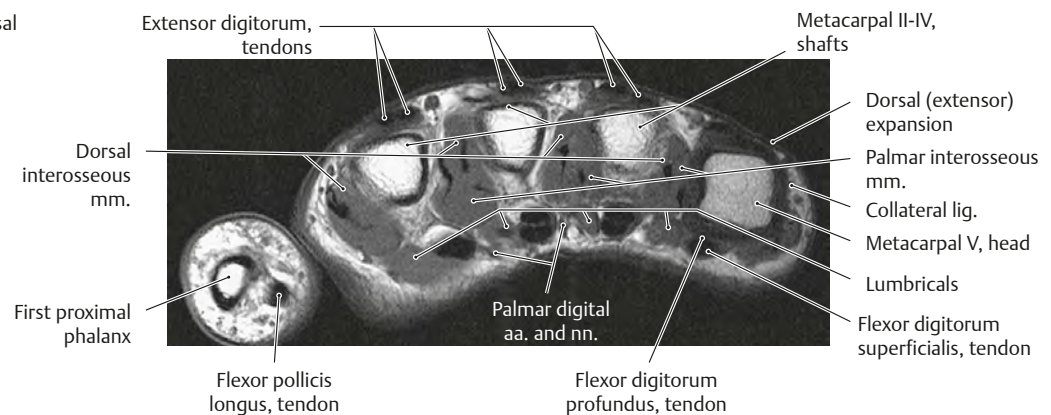
A Coronal section through the carpal tunnel.



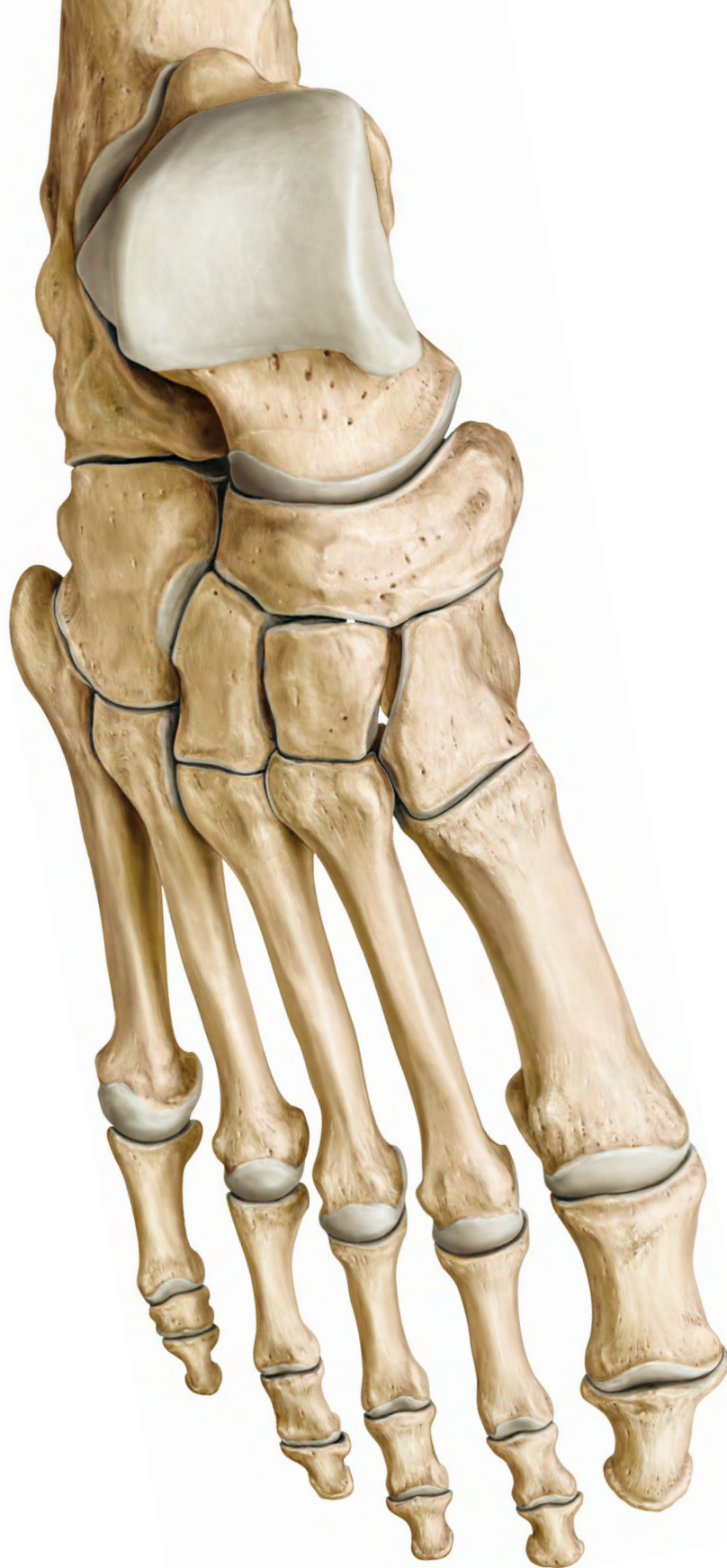
B Coronal section through the palm.



Dorsal
↑



C Transverse section through the palm, distal view.



Lower Limb

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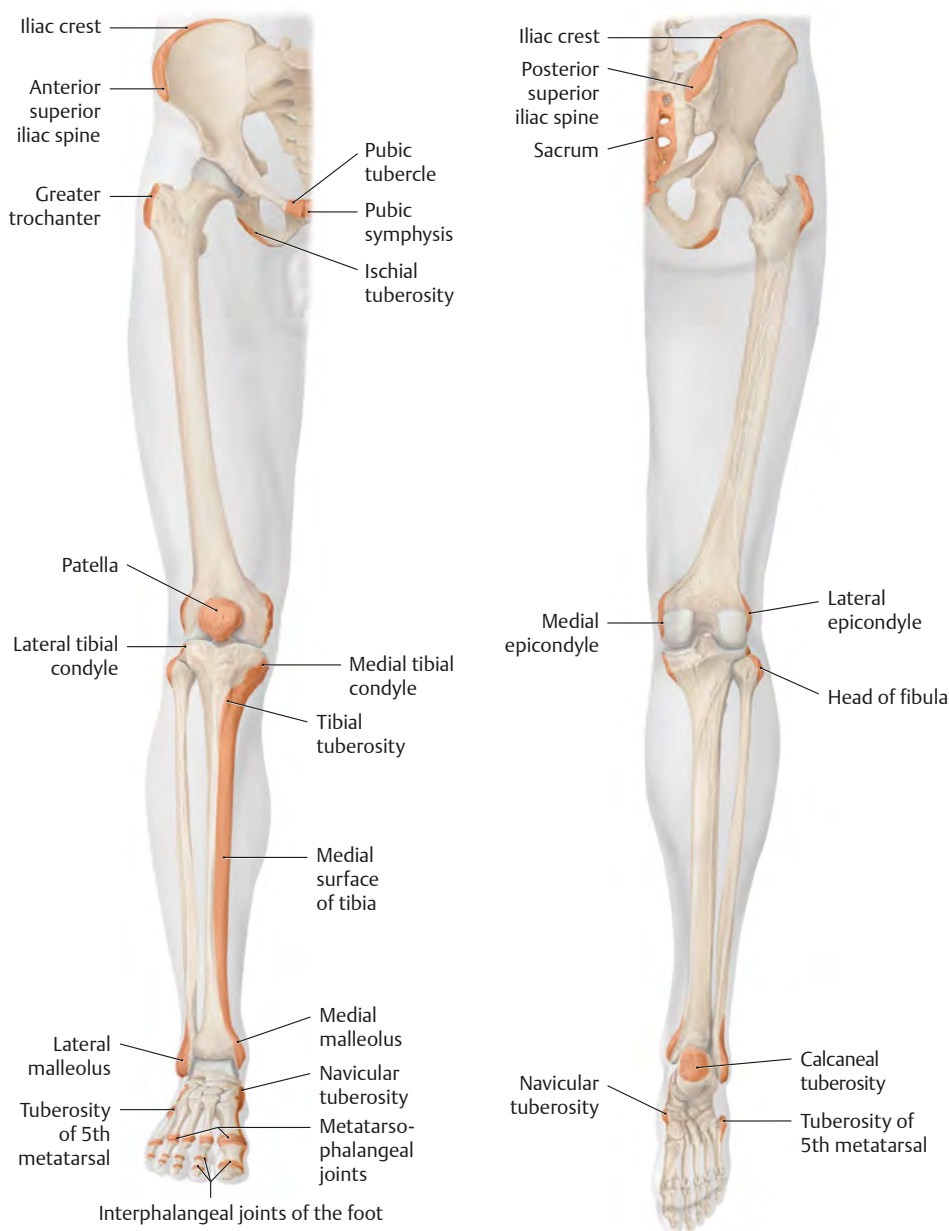
35 Sectional & Radiographic Anatomy

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30 Surface Anatomy

Surface Anatomy

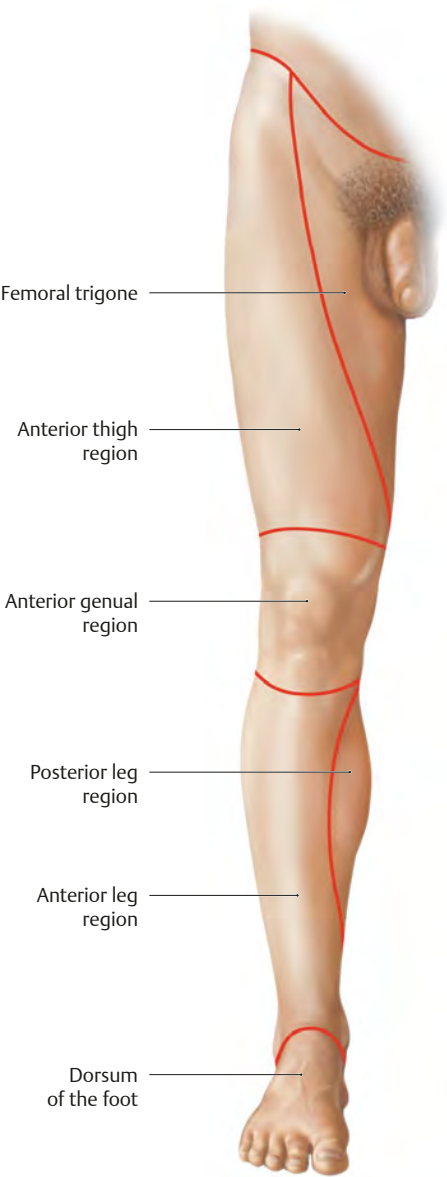
Fig. 30.1 Palpable bony prominences of the lower limb
Right limb.



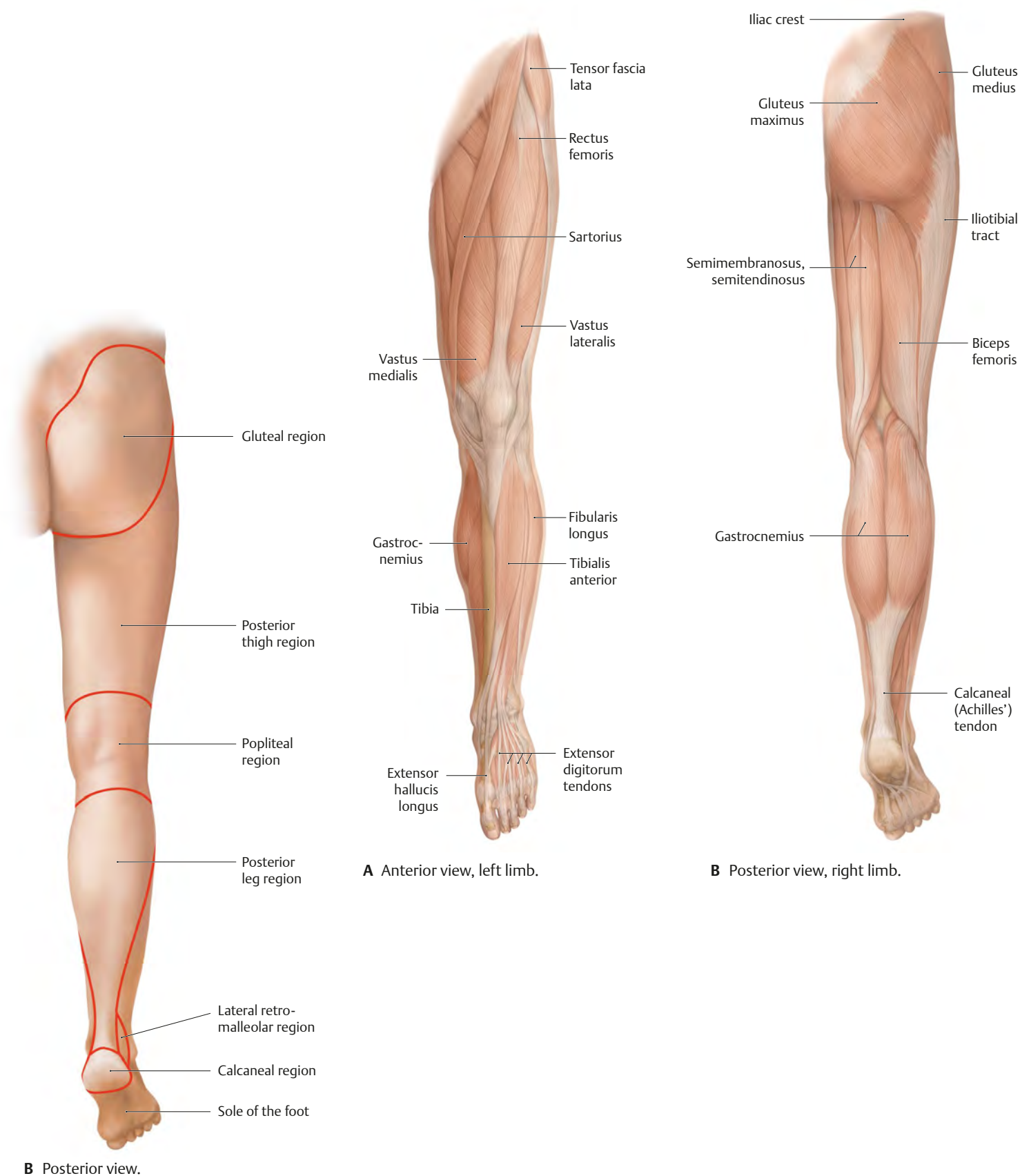
A Anterior view.

B Posterior view.

Fig. 30.2 Regions of the lower limb
Right leg.



A Anterior view.

Fig. 30.3 Palpable musculature of the lower limb

31 Hip & Thigh

Bones of the Lower Limb

The skeleton of the lower limb consists of a coxal (hip) bone and a free limb. The paired coxal bones attach to the trunk at the sacroiliac joint to form the pelvic girdle (see p. 230), and the free limb, divided into a

thigh, leg, and foot, attaches to the pelvic girdle at the hip joint. Stability of the pelvic girdle is important in the distribution of weight from the upper body to the lower limbs.

Fig. 31.1 Bones of the lower limb

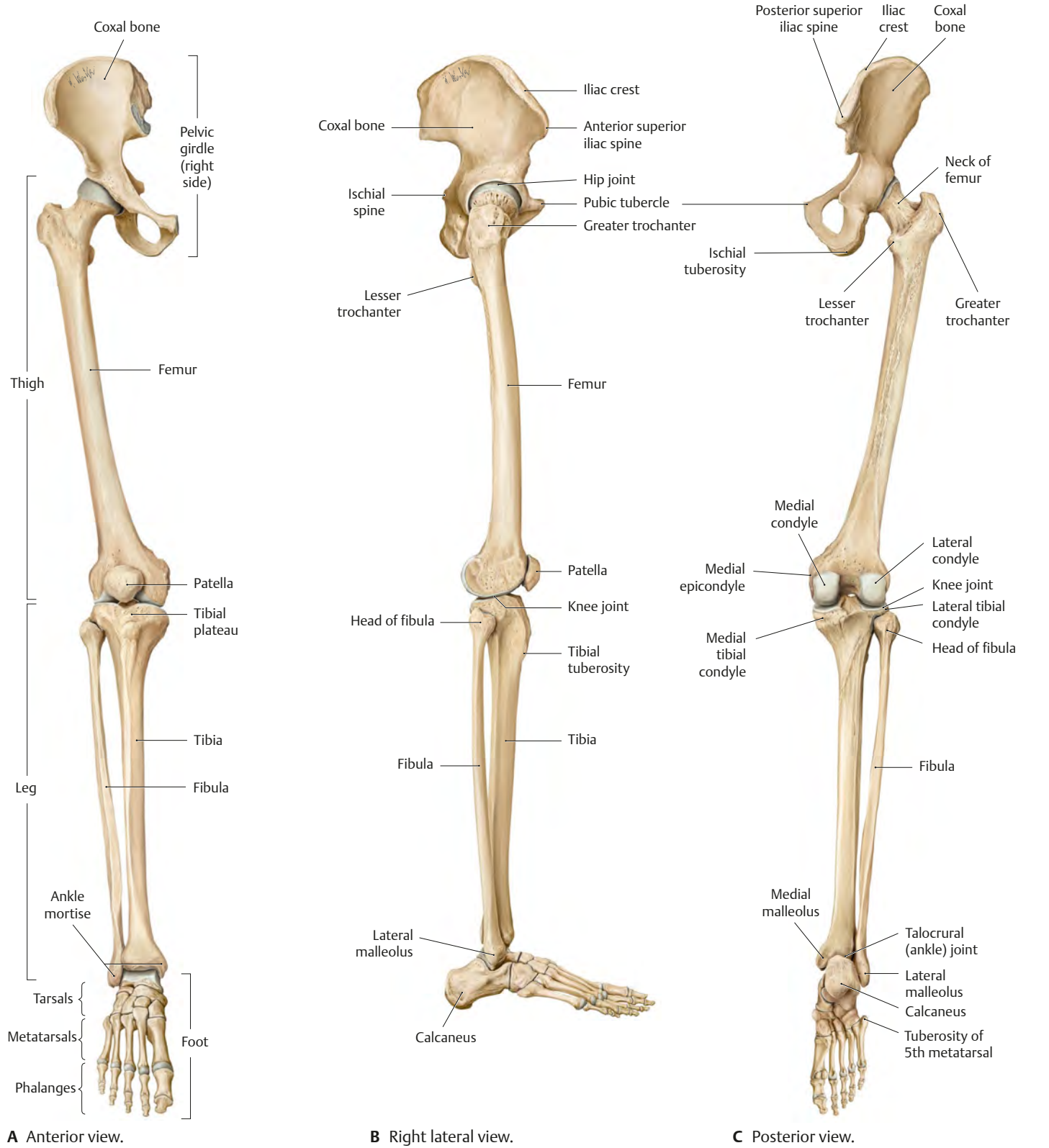
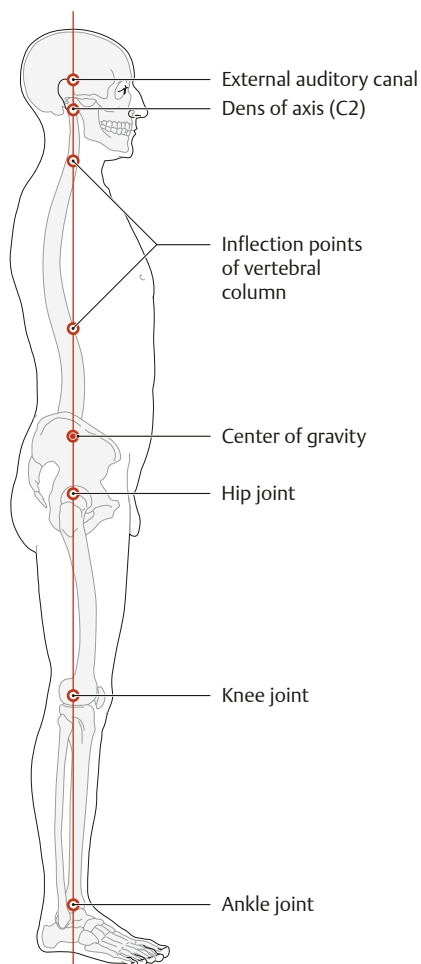


Fig. 31.2 Line of gravity

Right lateral view. The line of gravity runs vertically from the whole-body center of gravity to the ground with characteristic points of intersection.

**Fig. 31.3 The coxal bones and their relation to the vertebral column.**

The paired coxal bones and sacrum form the pelvic girdle (see p. 230).

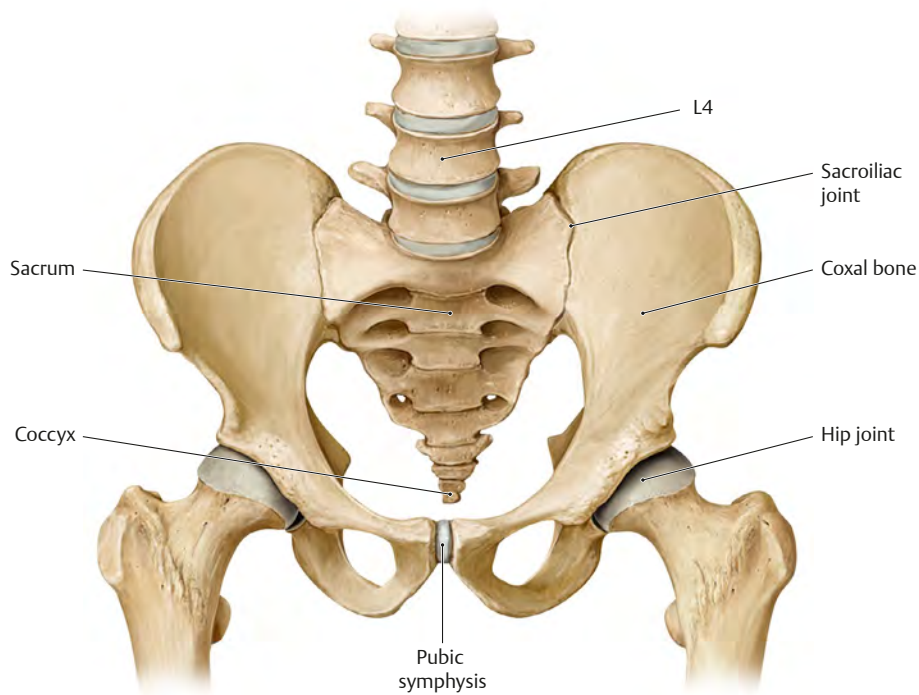
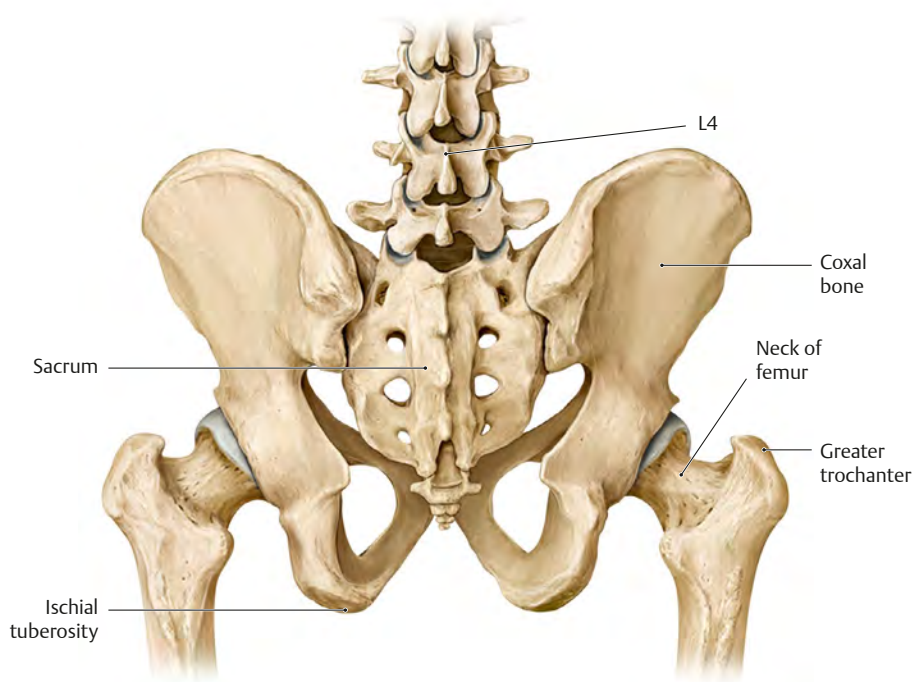
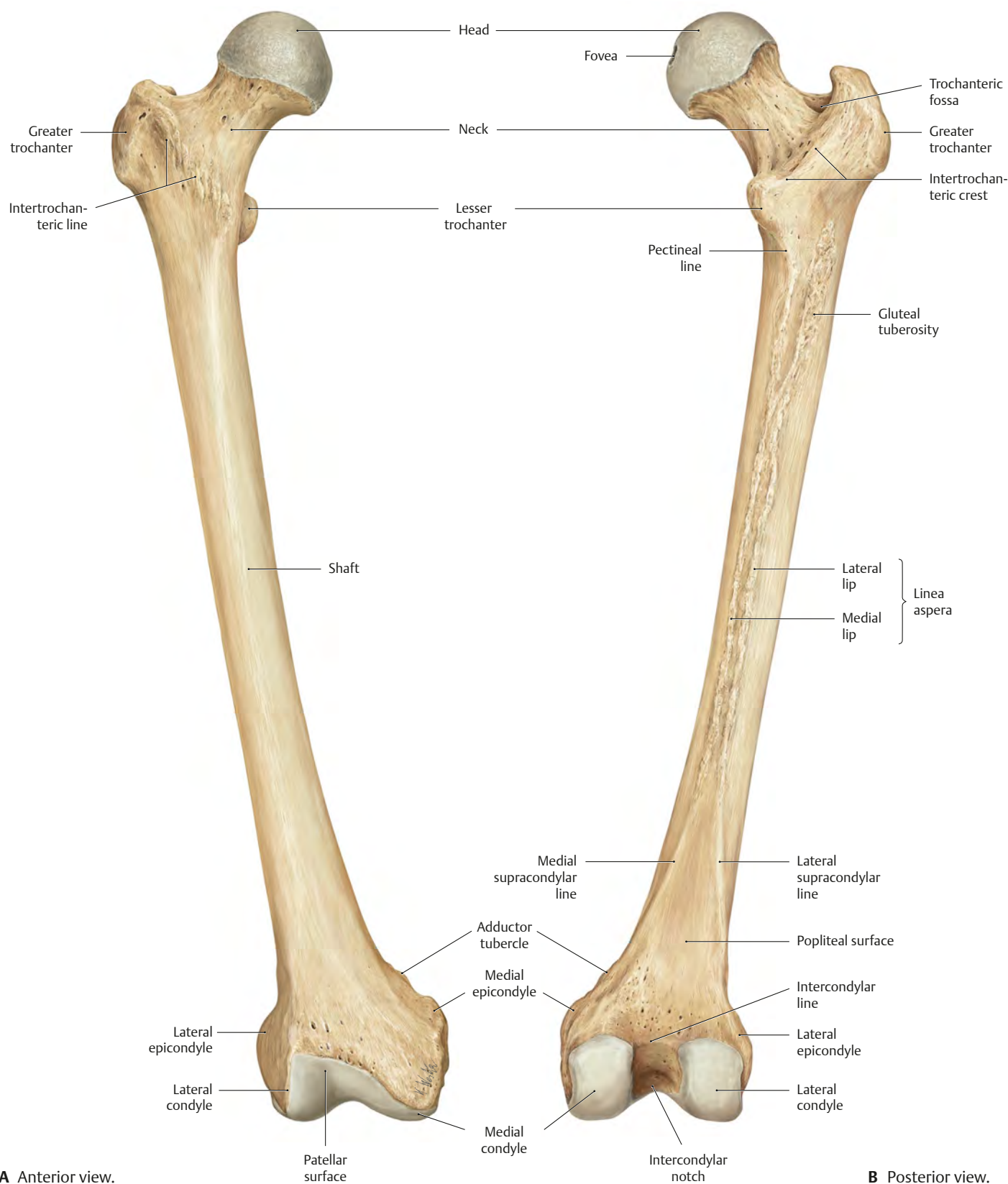
**A Anterior view.****B Posterior view.**

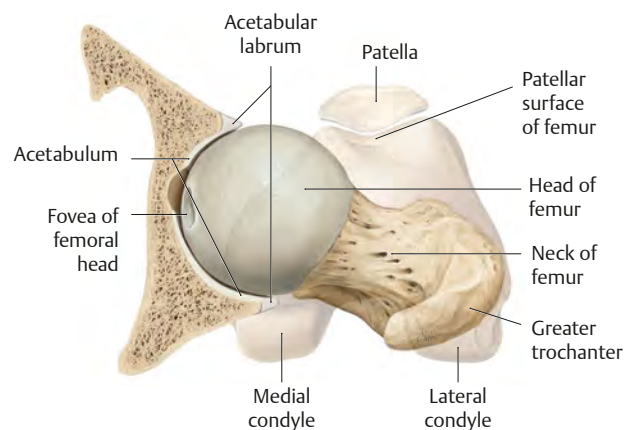
Fig. 31.4 Femur

Right femur. The femur articulates proximally with the acetabulum of the pelvis at the hip joint and distally with the tibia at the knee joint.

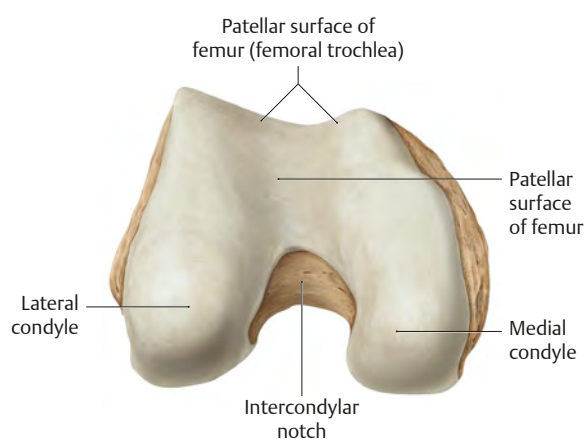


A Anterior view.

B Posterior view.



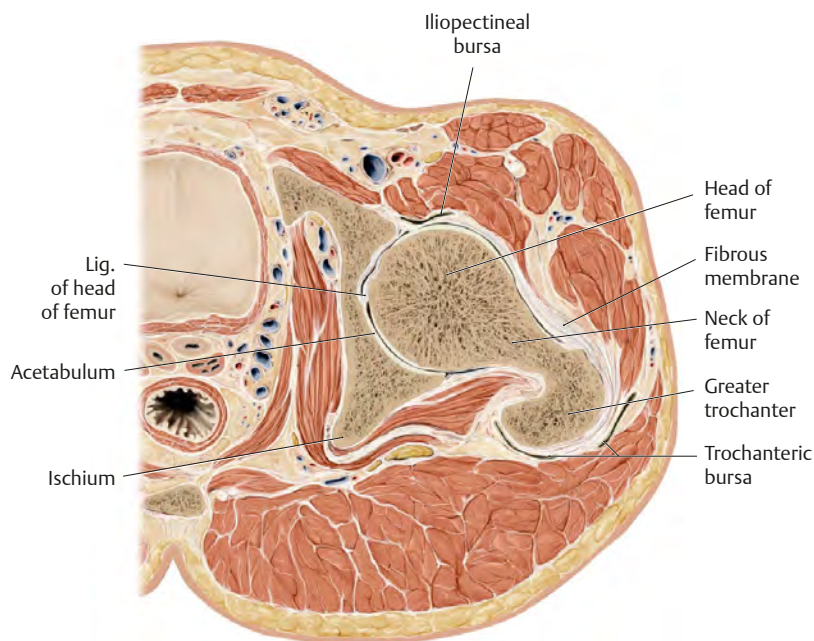
C Proximal view. The acetabulum has been sectioned in the horizontal plane.



D Distal view.

Fig. 31.5 Hip joint: Transverse section

Right hip joint, superior view.

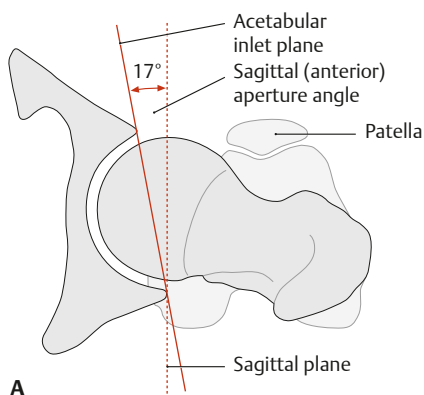


Clinical box 31.1

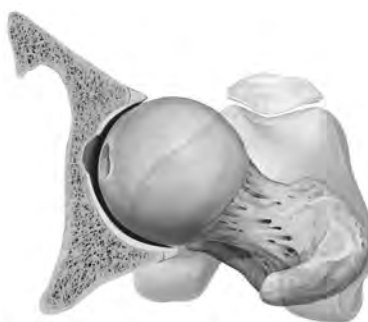
Rotation of the femoral head

The acetabular rim is oriented anteroinferiorly relative to the sagittal plane. At birth, the aperture angle measures approximately 7 degrees but increases to 17 degrees by adulthood (**A**). This angle affects the stability and “seating” of the femoral head in the hip joint. When the femoral head is centered in the

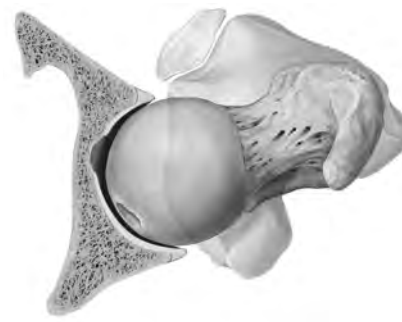
acetabulum, the distal femur and thus the knee joint, point slightly inward. Note how external (**B**) and internal (**C**) rotation of the femoral head affect the orientation of the knee joint.



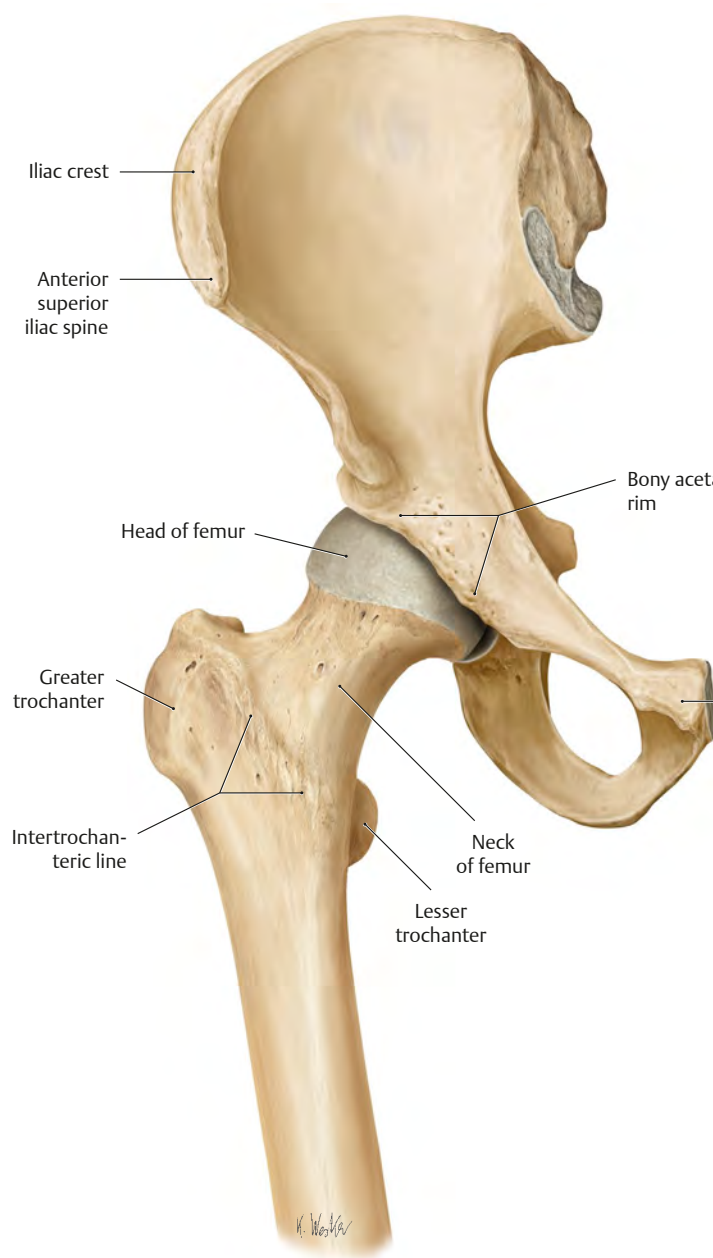
A



B



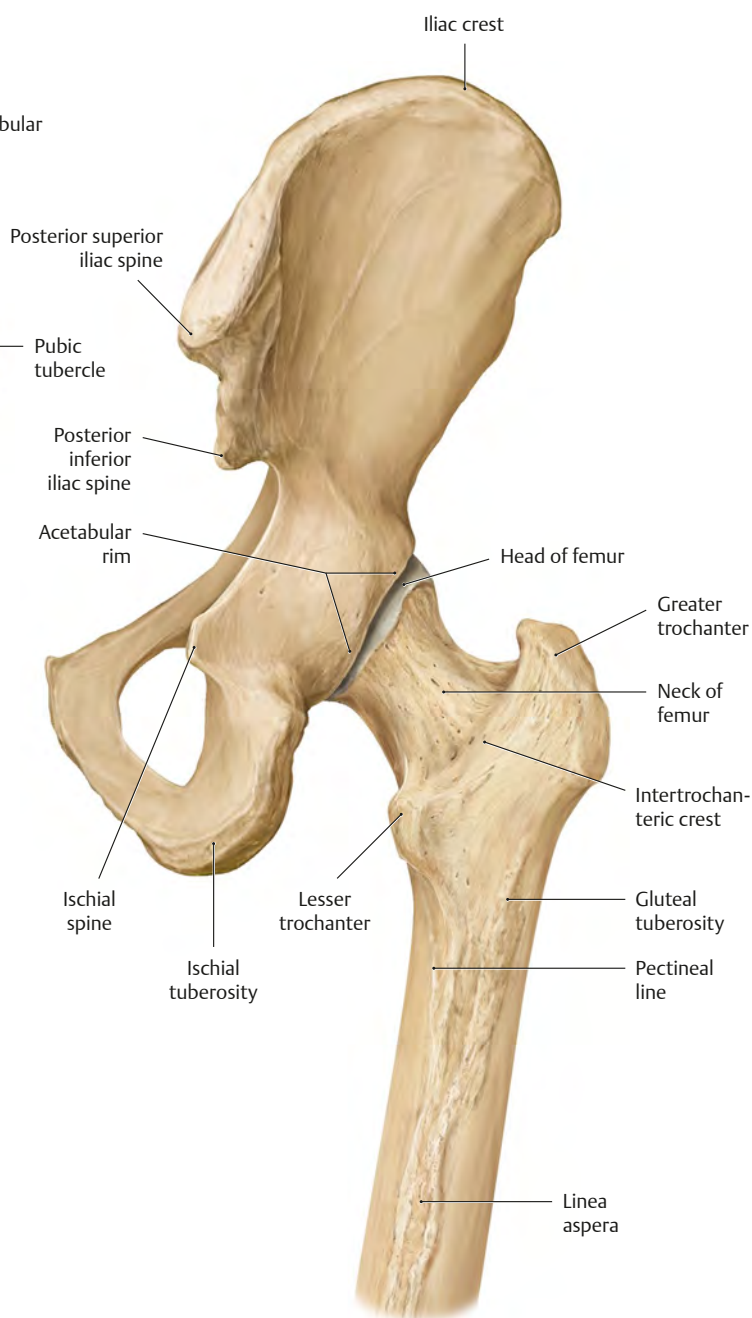
C



A Anterior view.

Fig. 31.6 Right hip joint

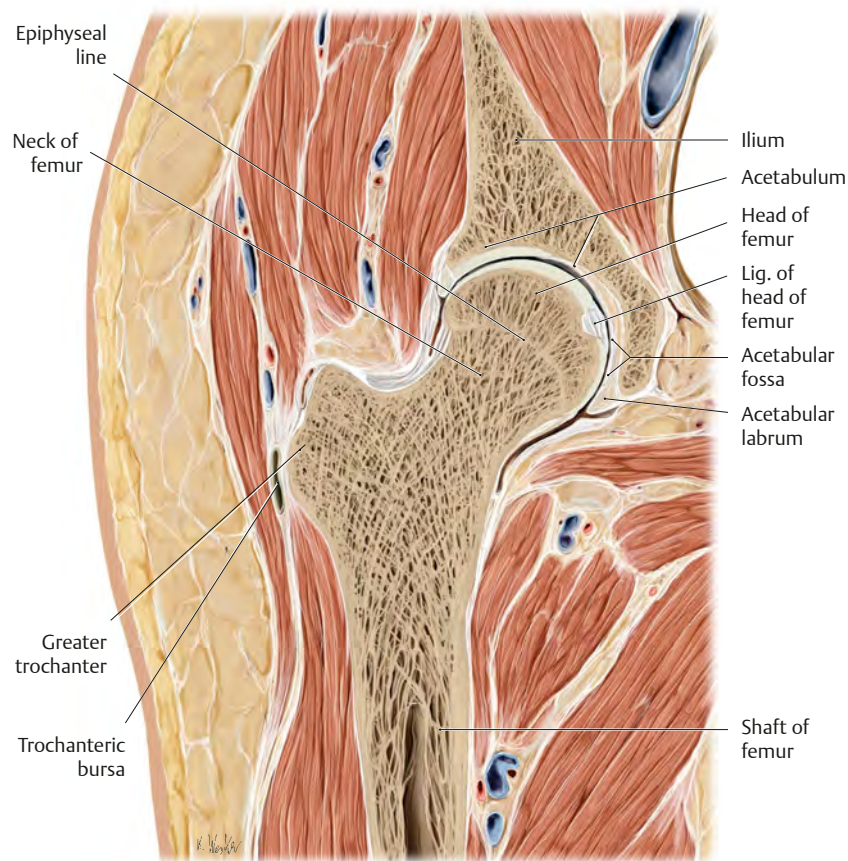
The head of the femur articulates with the acetabulum of the pelvis at the hip joint, a special type of spheroidal (ball-and-socket) joint. The roughly spherical femoral head (with an average radius of curvature of approximately 2.5 cm) is largely contained within the acetabulum.



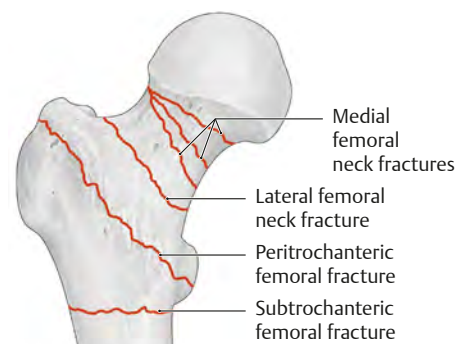
B Posterior view.

Fig. 31.7 Hip joint: Coronal section

Right hip joint, anterior view.

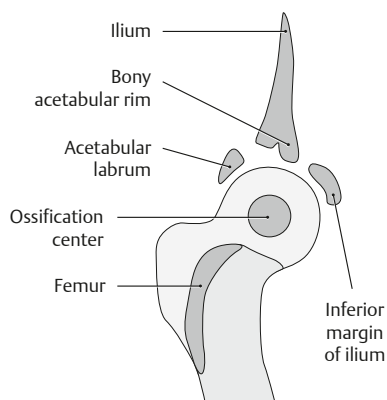
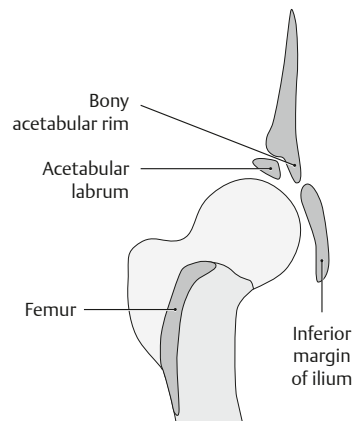
**Clinical box 31.2****Fractures of the femur**

Femoral fractures caused by falls in patients with osteoporosis are most frequently located in the neck of the femur. Femoral shaft fractures are less frequent and are usually caused by strong trauma (e.g., a car accident).

**Clinical box 31.3****Diagnosing hip dysplasia and dislocation**

Ultrasonography, the most important imaging method for screening the infant hip, is used to identify morphological changes such as hip dysplasia and dislocation. Clinically, hip dislocation presents with instability

and limited abduction of the hip joint, and leg shortening with asymmetry of the gluteal folds.

**A** Normal hip joint in a 5-month-old.**B** Hip dislocation and dysplasia in a 3-month-old.

Hip Joint: Ligaments & Capsule

The hip joint has three major ligaments: iliofemoral, pubofemoral, and ischiofemoral. The iliofemoral, the strongest of these, provides an important constraint for the hip joint: it prevents the pelvis from tilting posteriorly in the upright stance, without the need for muscular effort.

It also limits adduction of the extended limb and stabilizes the pelvis on the stance side during gait. A fourth ligament, the zona orbicularis (anular ligament) is not visible externally and encircles the femoral neck like a buttonhole.

Fig. 31.8 Ligaments of the hip joint
Right hip joint.

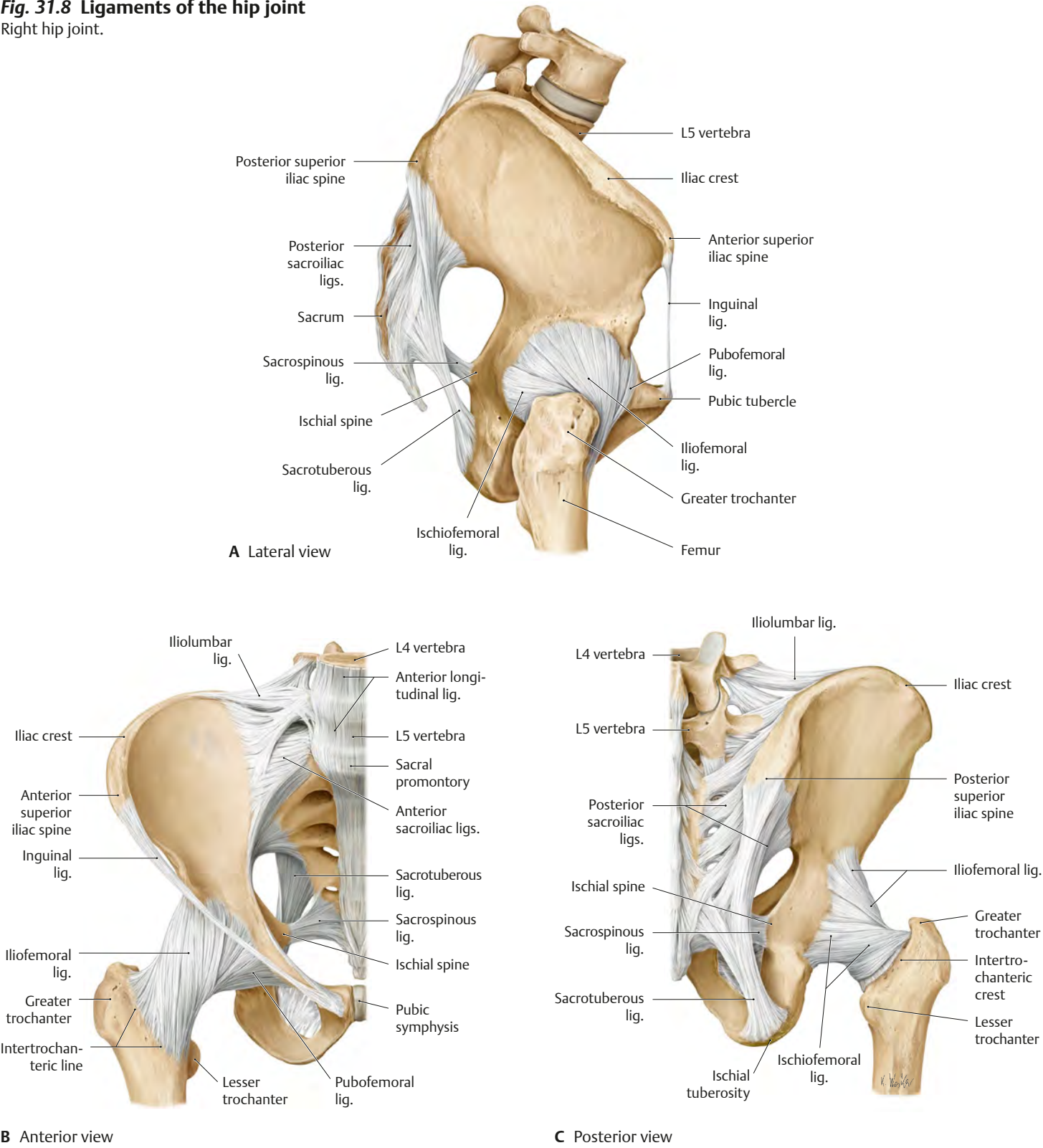
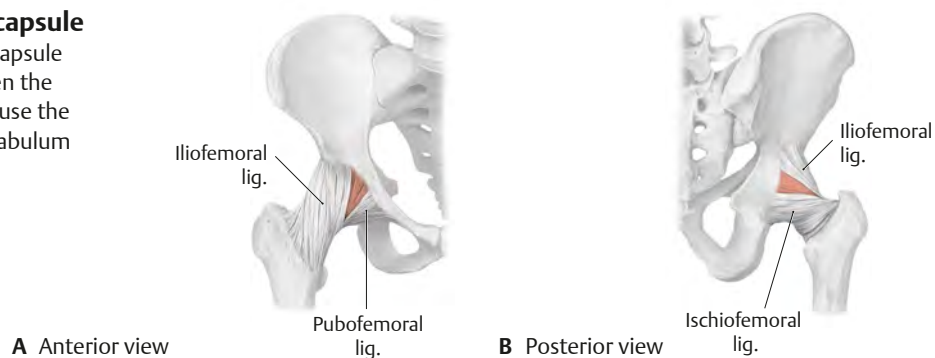
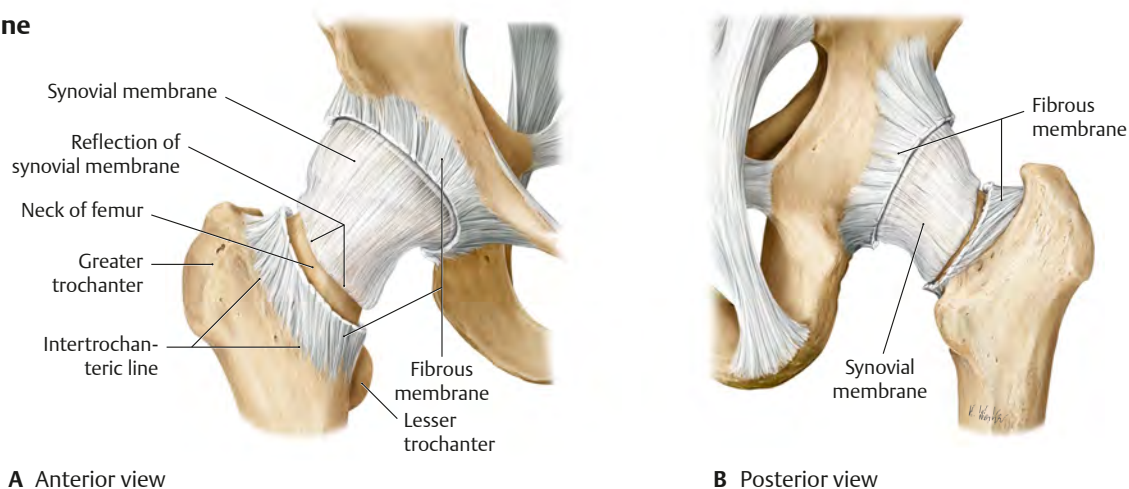
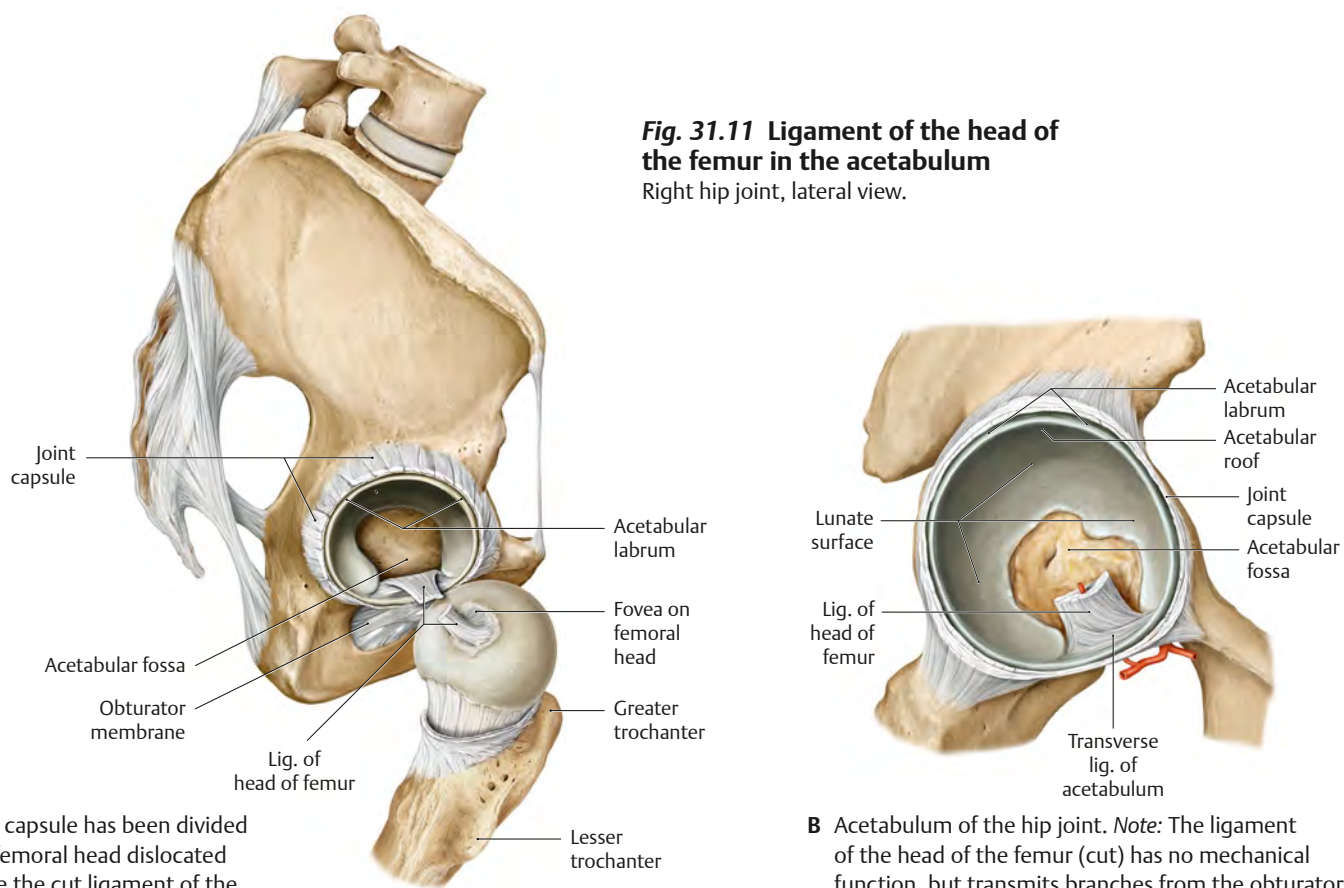


Fig. 31.9 Weakness in the joint capsule

Right hip joint. Weak spots in the joint capsule (color-shaded areas) are located between the joint ligaments. External trauma may cause the femoral head to dislocate from the acetabulum at these sites.

**Fig 31.10 Synovial membrane of the joint capsule****Fig. 31.11 Ligament of the head of the femur in the acetabulum**

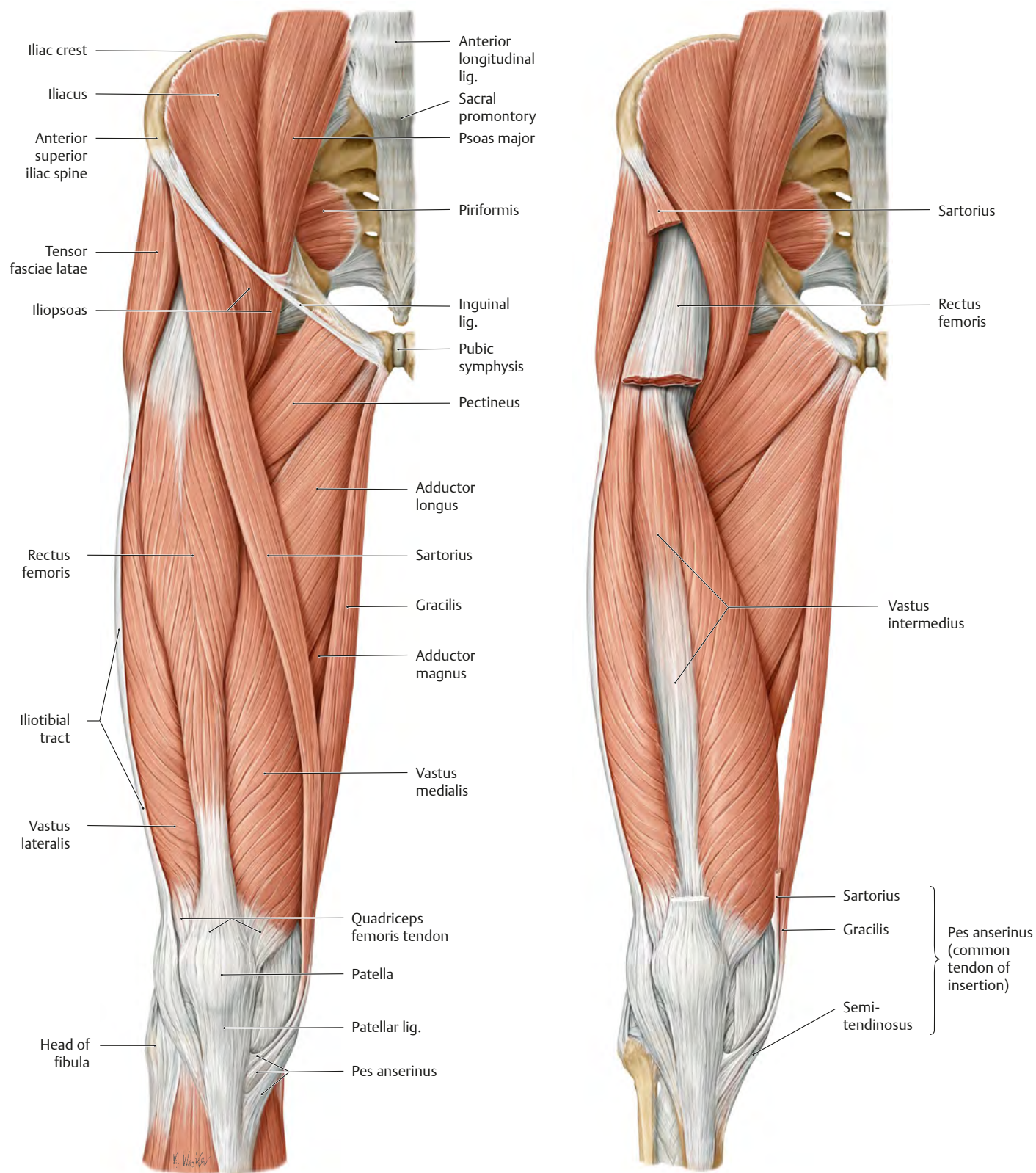
Right hip joint, lateral view.



Anterior Muscles of the Hip, Thigh & Gluteal Region (I)

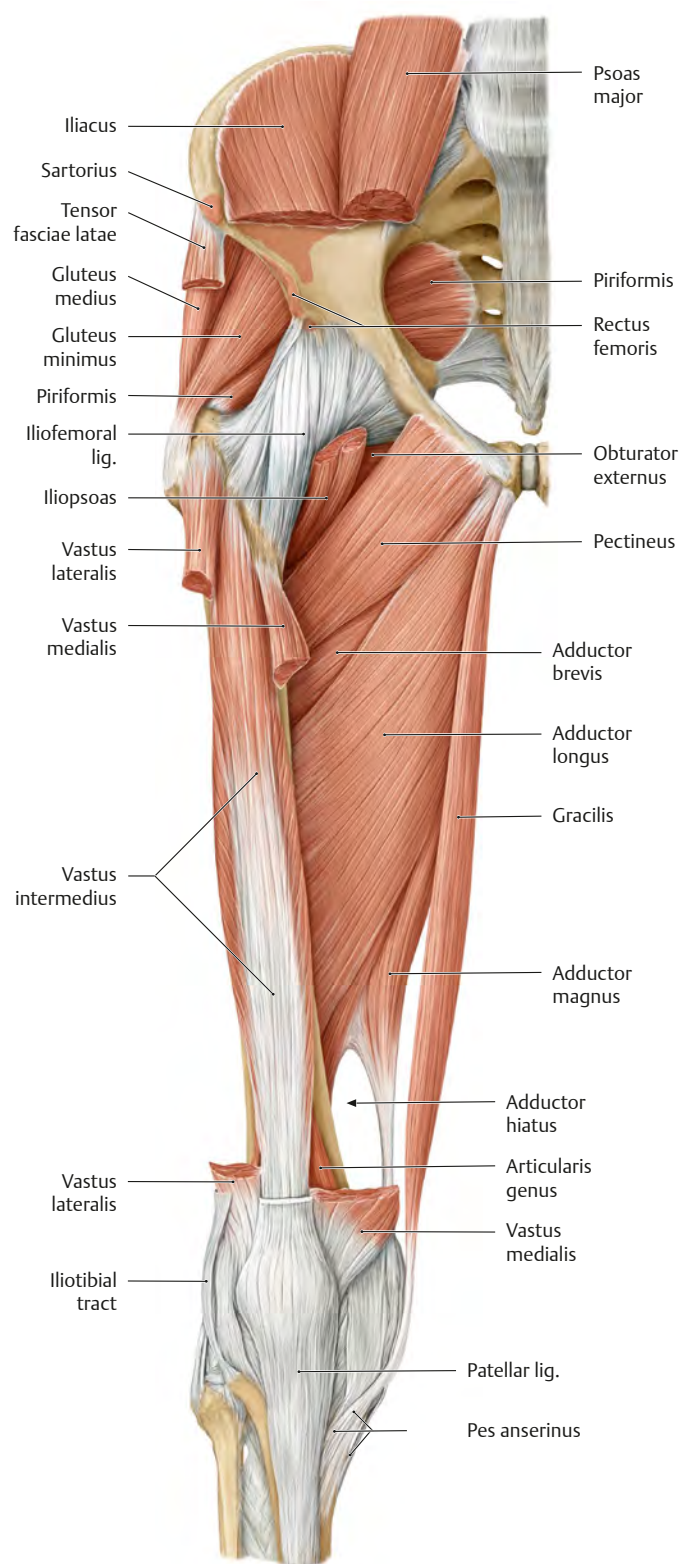
Fig. 31.12 Anterior muscles of the hip and thigh (I)

Right limb. Muscle origins are shown in red, insertions in blue.

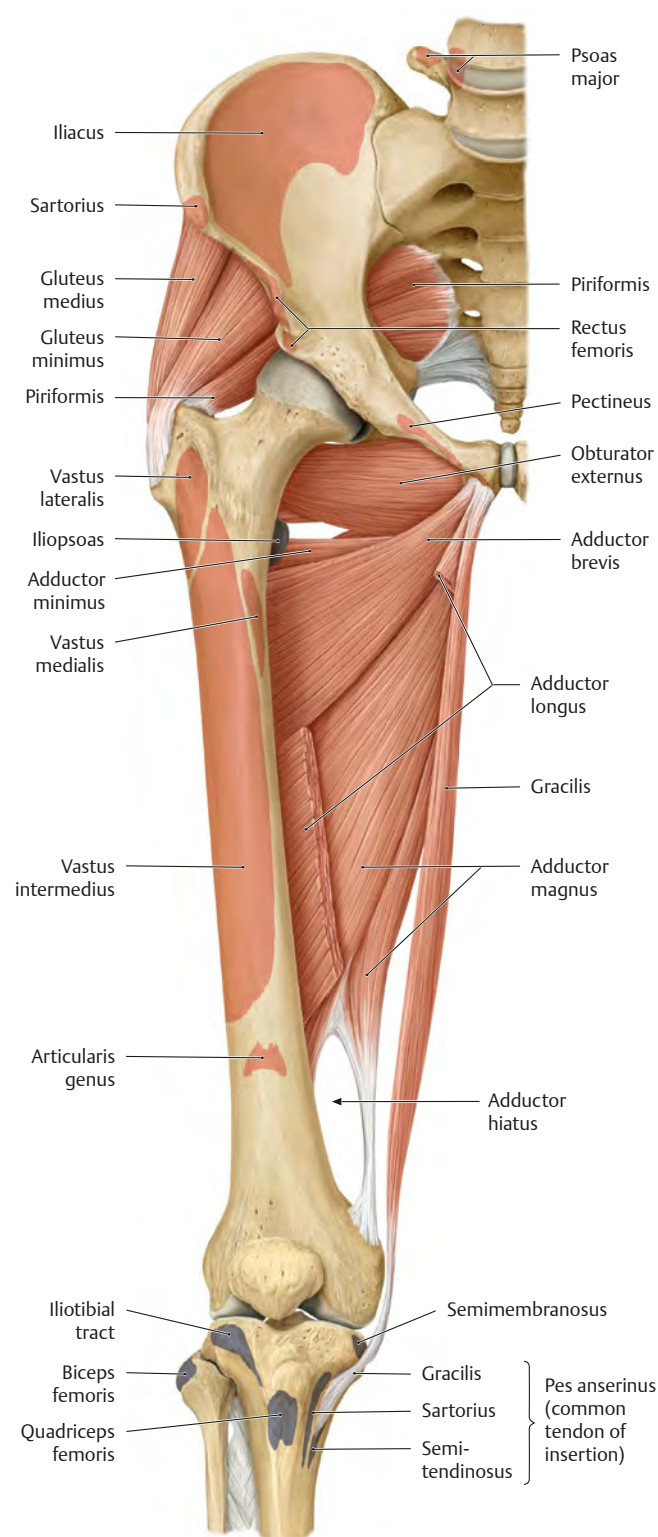


A Removed: Fascia lata of thigh (to the lateral iliotibial tract).

B Removed: Inguinal ligament, sartorius and rectus femoris.



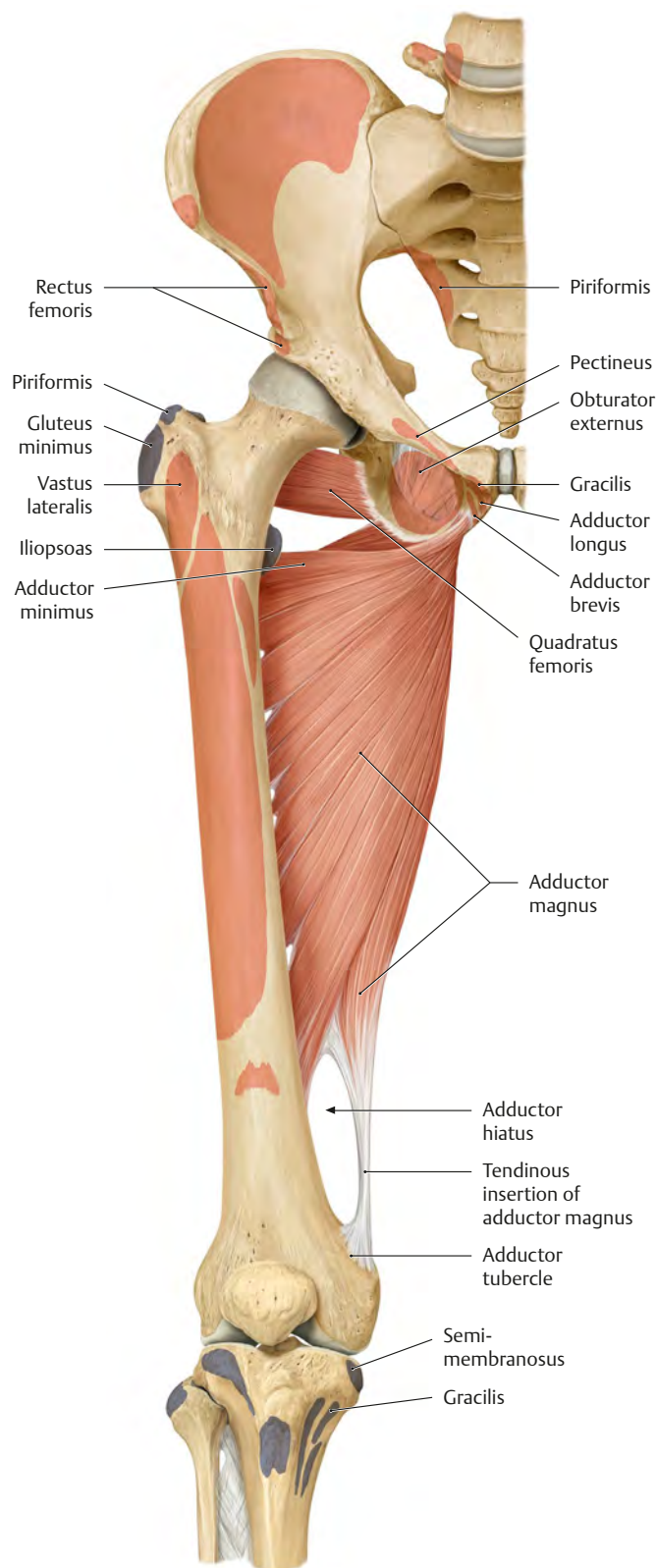
C Removed: Rectus femoris (completely), vastus lateralis, vastus medialis, iliopsoas, and tensor fasciae latae.



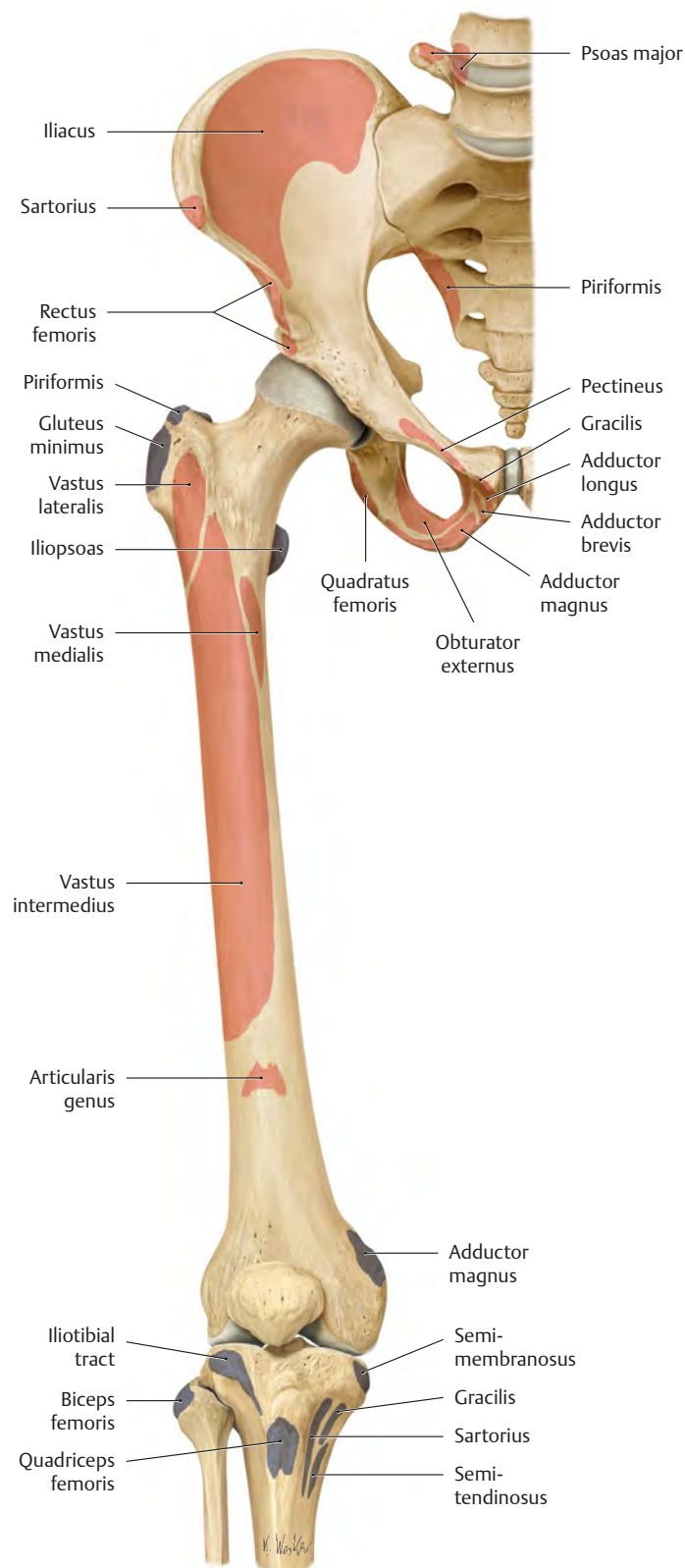
D Removed: Quadriceps femoris (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), iliopsoas, tensor fasciae latae, pectineus, and midportion of adductor longus.

Anterior Muscles of the Hip, Thigh & Gluteal Region (II)

Fig. 31.13 Anterior muscles of the hip and thigh (II)
Right limb. Muscle origins are shown in red, insertions in blue.

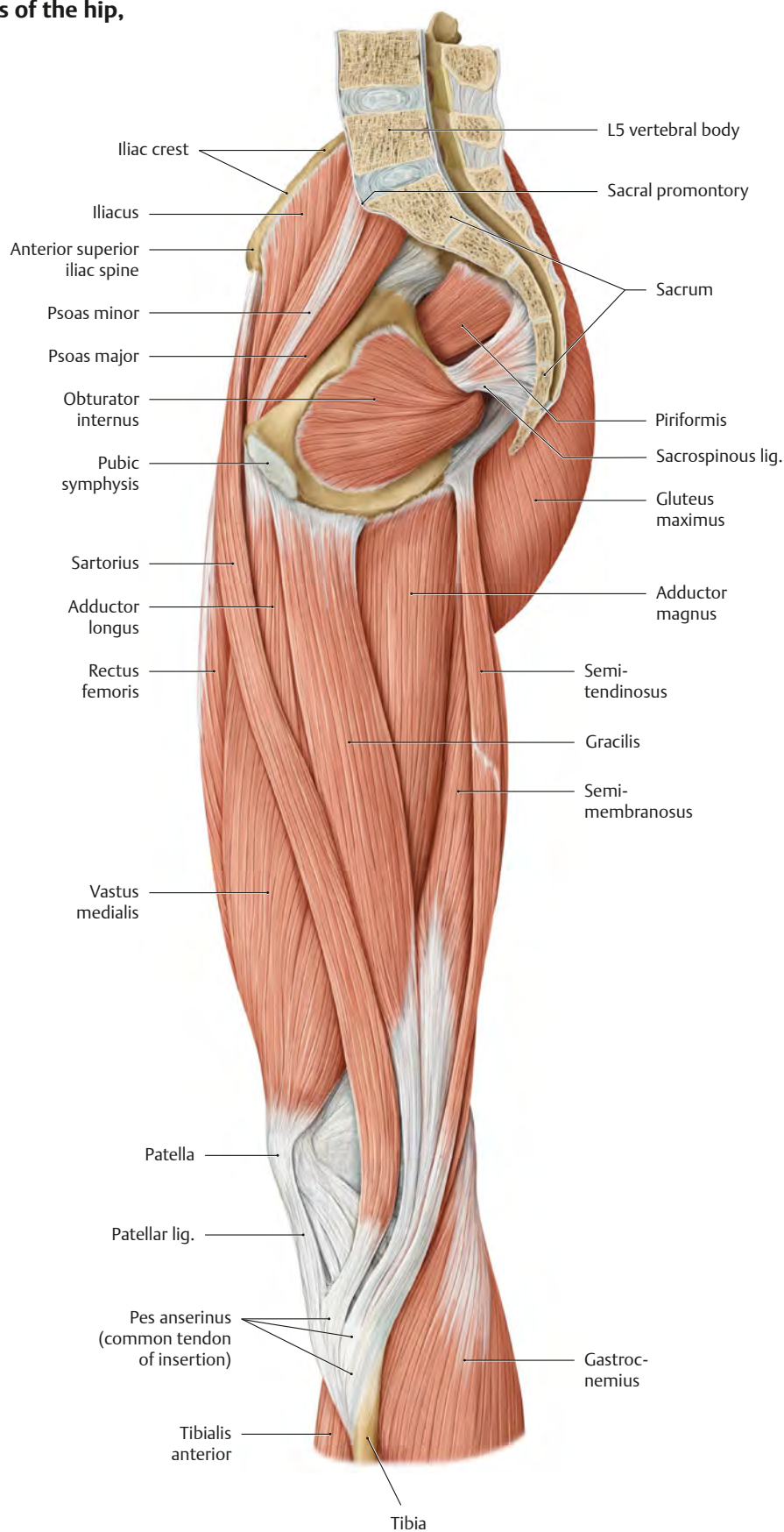


A Removed: Gluteus medius and minimus, piriformis, obturator externus, adductor brevis and longus, and gracilis.



B Removed: All muscles.

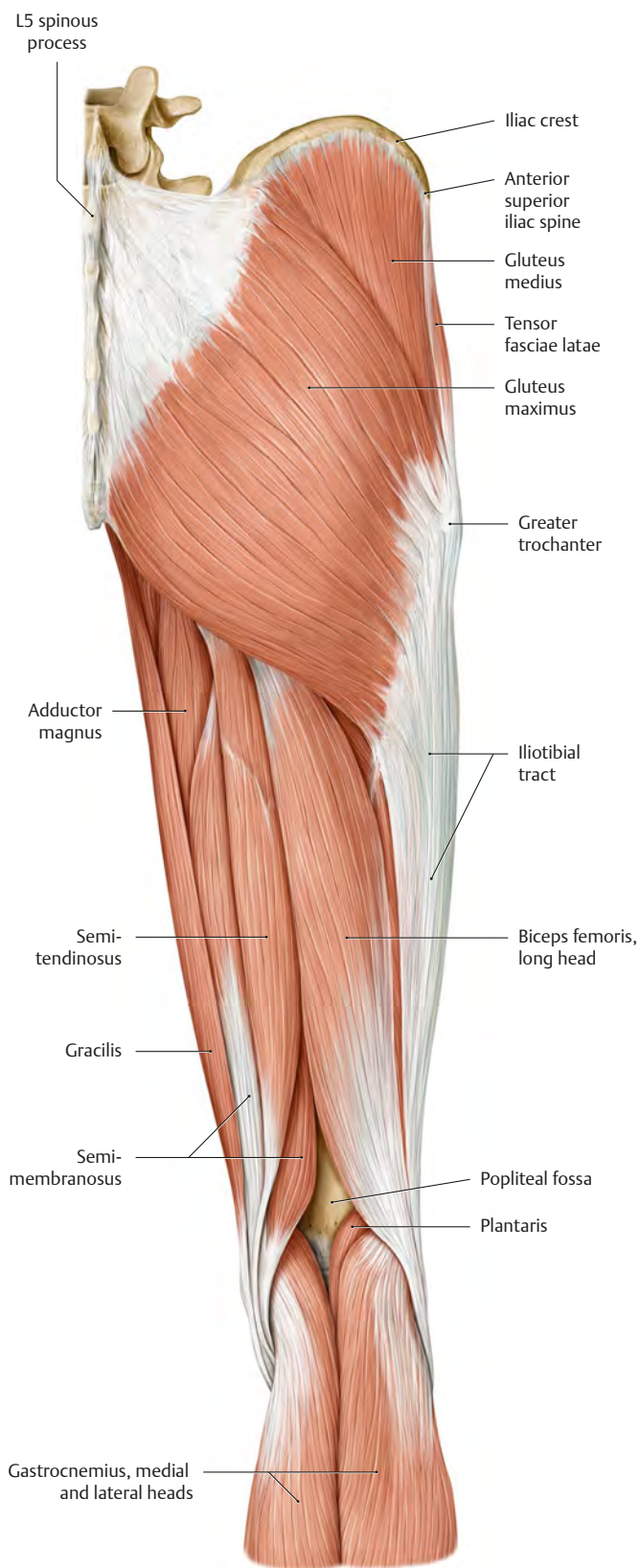
Fig. 31.14 Medial muscles of the hip, thigh, and gluteal region
Midsagittal section.



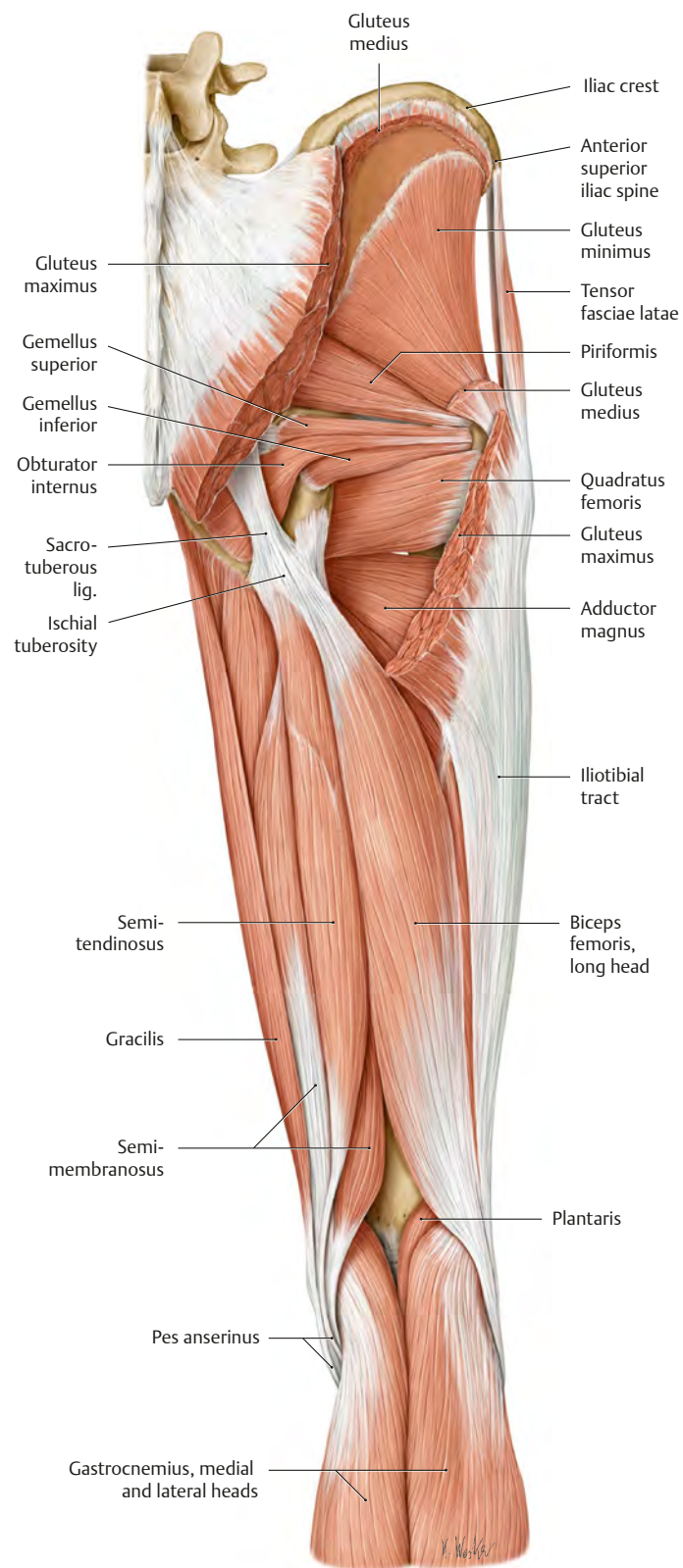
Posterior Muscles of the Hip, Thigh & Gluteal Region (I)

Fig. 31.15 Posterior muscles of the hip, thigh, and gluteal region (I)

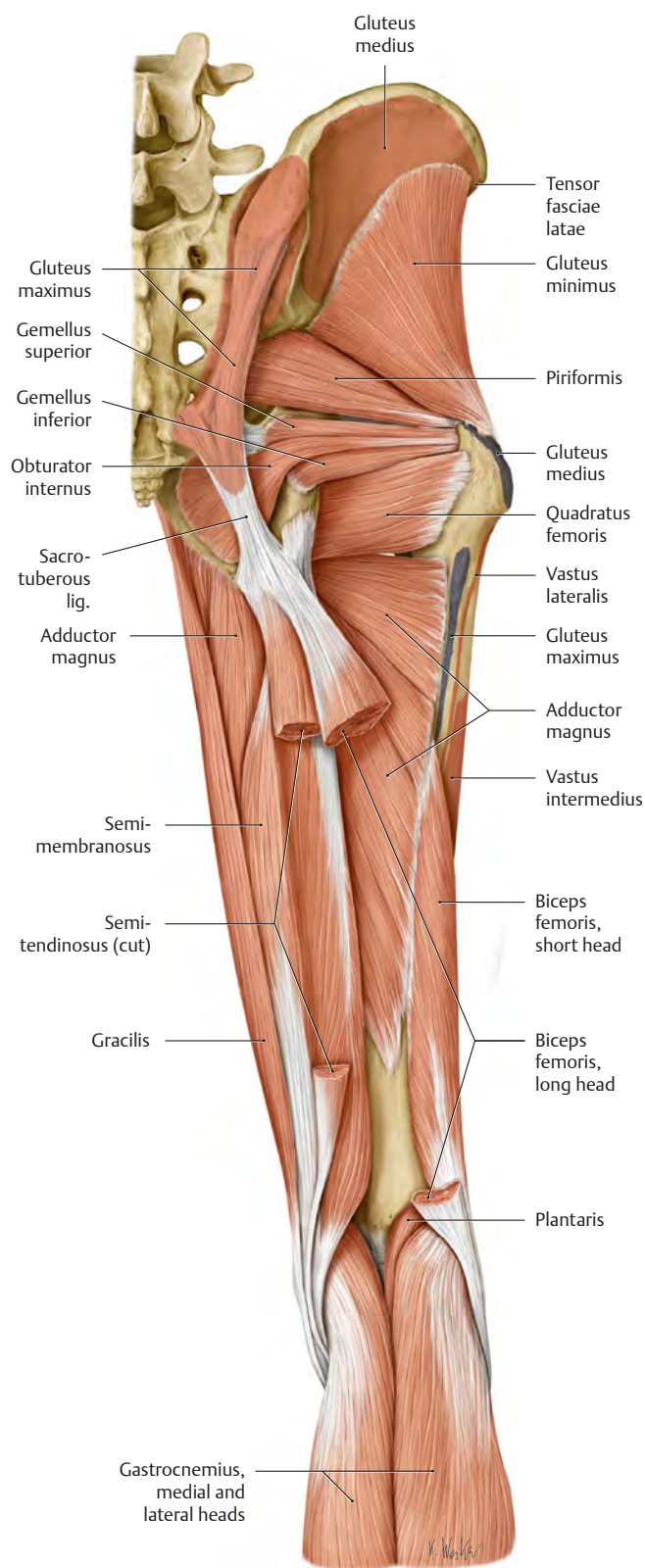
Right limb. Muscle origins are shown in red, insertions in blue.



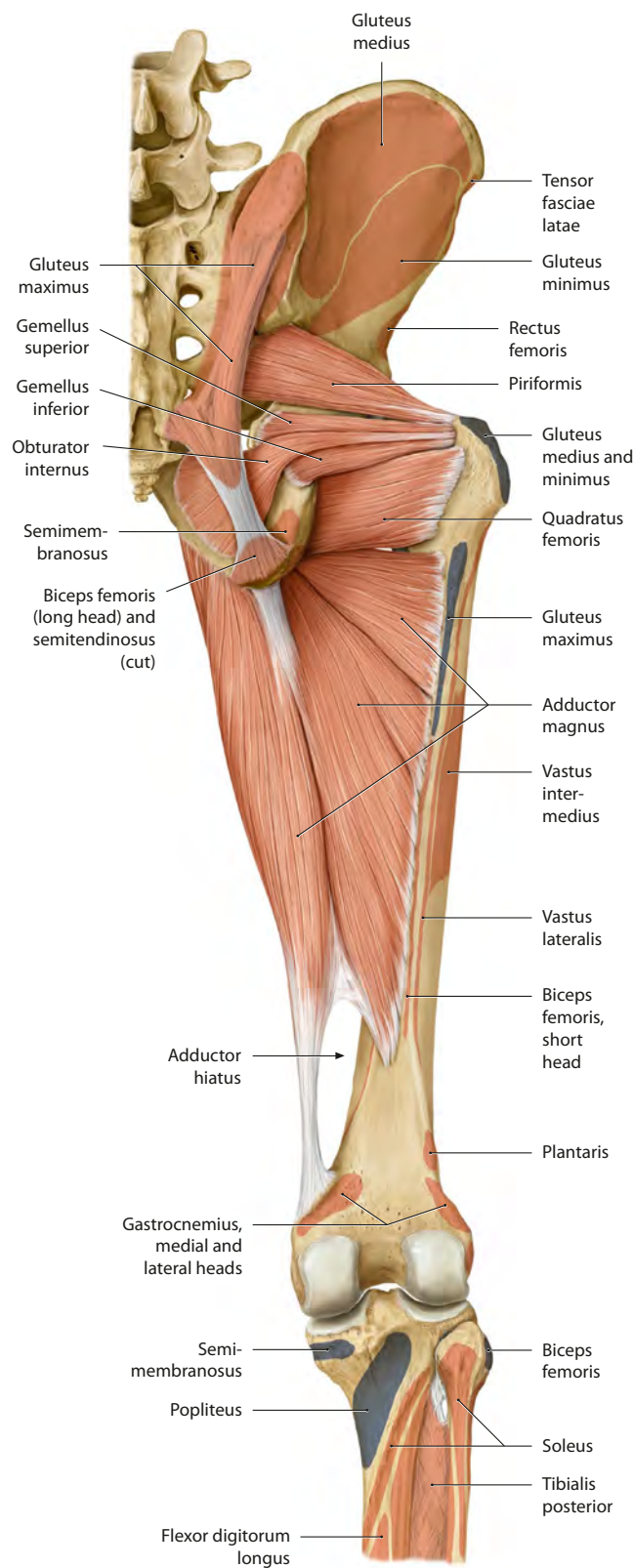
A Removed: Fascia lata (to iliotibial tract).



B Partially removed: Gluteus maximus and medius.



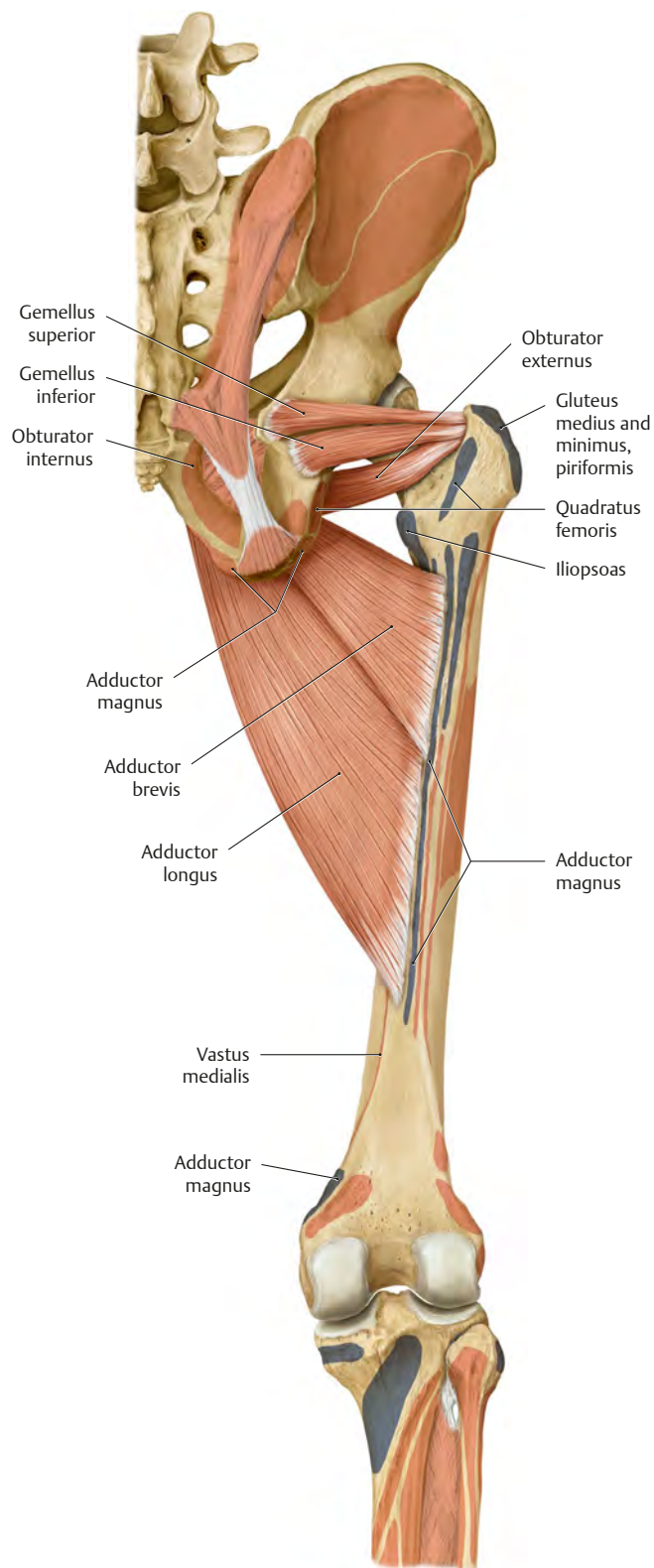
C Removed: Semitendinosus and biceps femoris (partially); gluteus maximus and medius (completely).



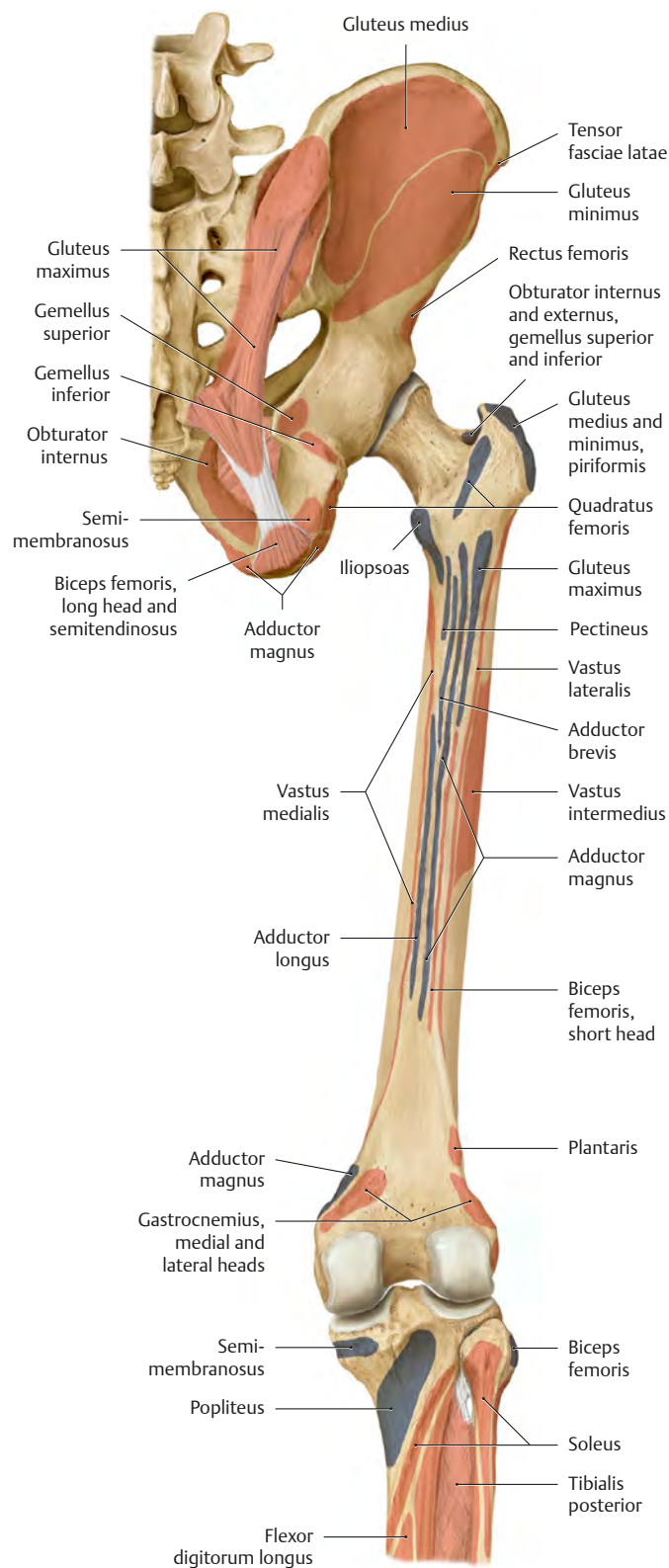
D Removed: Hamstrings (semitendinosus, semimembranosus, and biceps femoris), gluteus minimus, gastrocnemius, and muscles of the leg.

Posterior Muscles of the Hip, Thigh & Gluteal Region (II)

Fig. 31.16 Posterior muscles of the hip, thigh, and gluteal region (II)
Right limb. Muscle origins are shown in red, insertions in blue.



A Removed: Piriformis, obturator internus, quadratus femoris, and adductor magnus.



B Removed: All muscles.

Fig. 31.17 Lateral muscles of the hip, thigh, and gluteal region

Note: The iliotibial tract (the thickened band of fascia lata) functions as a tension band to reduce the bending loads on the proximal femur.

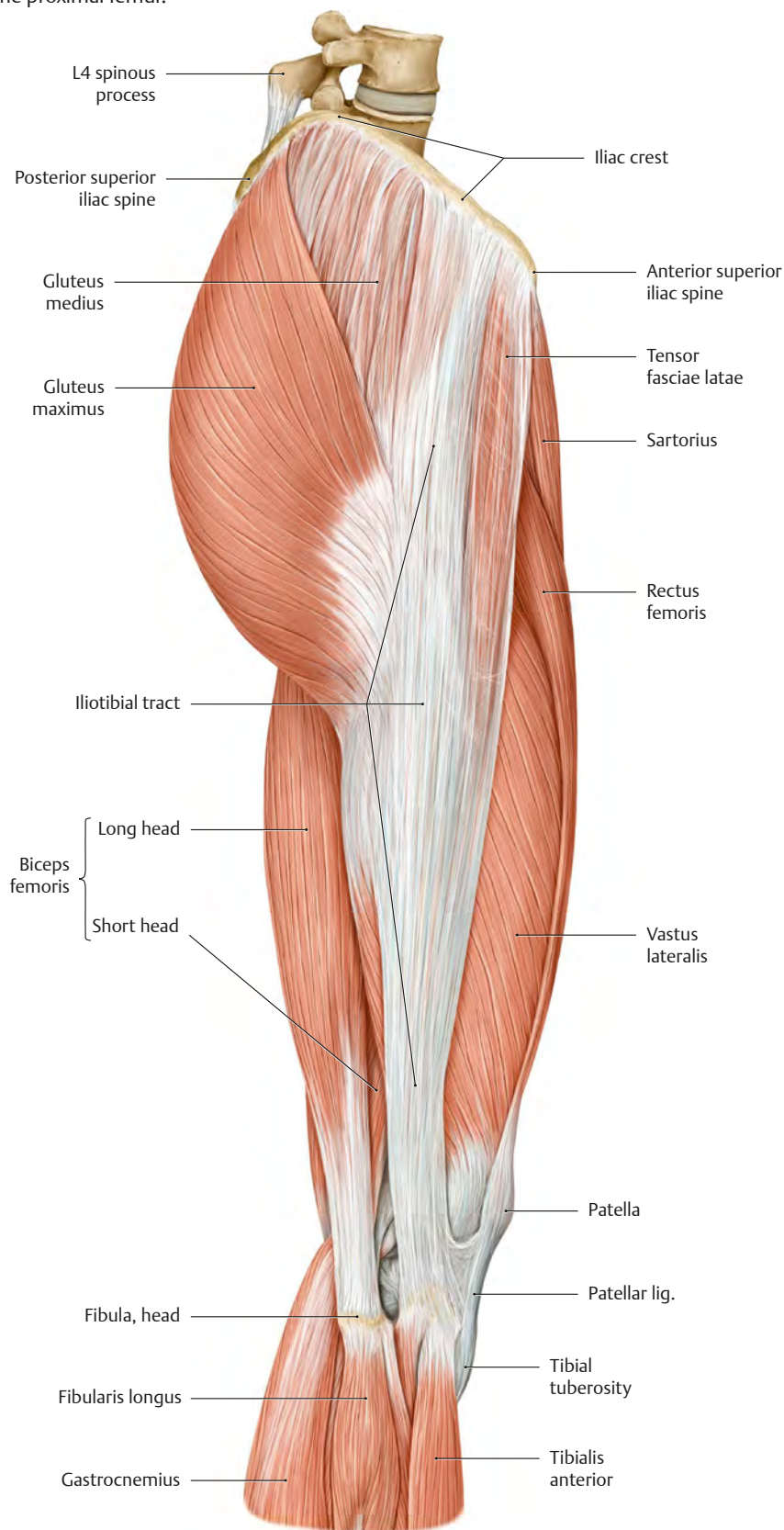


Table 31.1

Iliopsoas muscle

Muscles	Origin	Insertion	Innervation	Action
③ Iliopsoas	① Psoas major*	Femur (lesser trochanter)	Lumbar plexus L1, L2(L3)	- Hip joint: flexion and external rotation - Lumbar spine: <i>unilateral</i> contraction (with the femur fixed) flexes the trunk laterally to the same side; <i>bilateral</i> contraction raises the trunk from the supine position
	② Iliacus		Femoral n. (L2–L3)	

* The psoas minor, present in approximately 50% of the population, is often found on the superficial surface of the psoas major (see Fig. 31.19). It is not a muscle of the lower limb. It originates, inserts, and exerts its action on the abdomen (see Table 13.1, p. 148).

Fig. 31.18 Muscles of the hip

Right side, schematic.

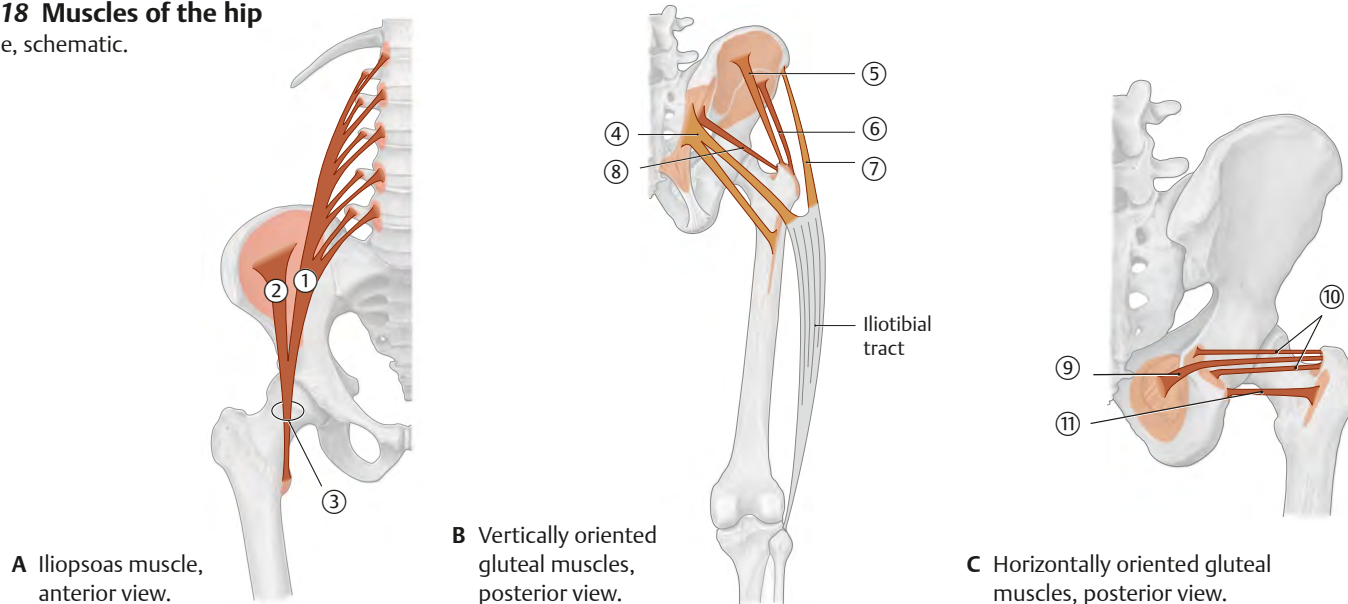


Table 31.2

Gluteal muscles

Muscle	Origin	Insertion	Innervation	Action
④ Gluteus maximus	Sacrum (dorsal surface, lateral part), ilium (gluteal surface, posterior part), thoracolumbar fascia, sacrotuberous lig.	- Upper fibers: iliotibial tract - Lower fibers: gluteal tuberosity	Inferior gluteal n. (L5–S2)	- Entire muscle: extends and externally rotates the hip in sagittal and coronal planes - Upper fibers: abduction - Lower fibers: adduction
⑤ Gluteus medius	Ilium (gluteal surface below the iliac crest between the anterior and posterior gluteal line)	Greater trochanter of the femur (lateral surface)	Superior gluteal n. (L4–S1)	- Entire muscle: abducts the hip, stabilizes the pelvis in the coronal plane - Anterior part: flexion and internal rotation - Posterior part: extension and external rotation
⑥ Gluteus minimus	Ilium (gluteal surface below the origin of gluteus medius)	Greater trochanter of the femur (anterolateral surface)		- Tenses the fascia lata - Hip joint: abduction, flexion, and internal rotation
⑦ Tensor fasciae latae	Anterior superior iliac spine	Iliotibial tract	Sacral plexus (S1, S2)	- External rotation, abduction, and extension of the hip joint - Stabilizes the hip joint
⑧ Piriformis	Pelvic surface of the sacrum	Apex of the greater trochanter of the femur		External rotation and extension of the hip joint (also active in abduction, depending on the joint's position)
⑨ Obturator internus	Inner surface of the obturator membrane and its bony boundaries	Medial surface of the greater trochanter	Sacral plexus (L5, S1)	External rotation of the hip joint
⑩ Gemelli	- Gemellus superior: ischial spine - Gemellus inferior: ischial tuberosity	Jointly with obturator internus tendon (medial surface, greater trochanter)		
⑪ Quadratus femoris	Lateral border of the ischial tuberosity	Intertrochanteric crest of the femur		

Fig. 31.19 Psoas and iliacus muscles
Right side, anterior view.

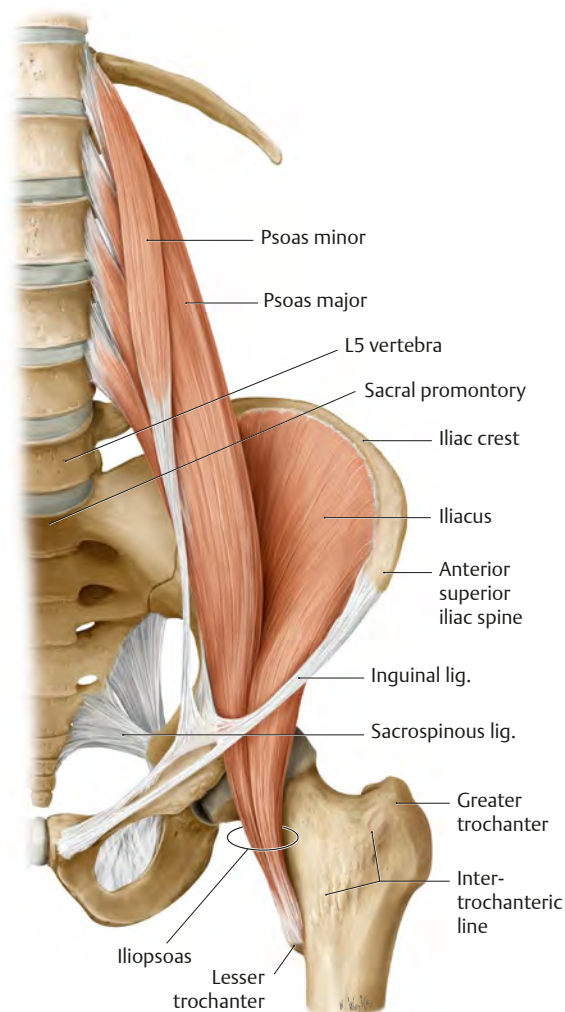


Fig. 31.20 Superficial muscles of the gluteal region
Right side, posterior view.

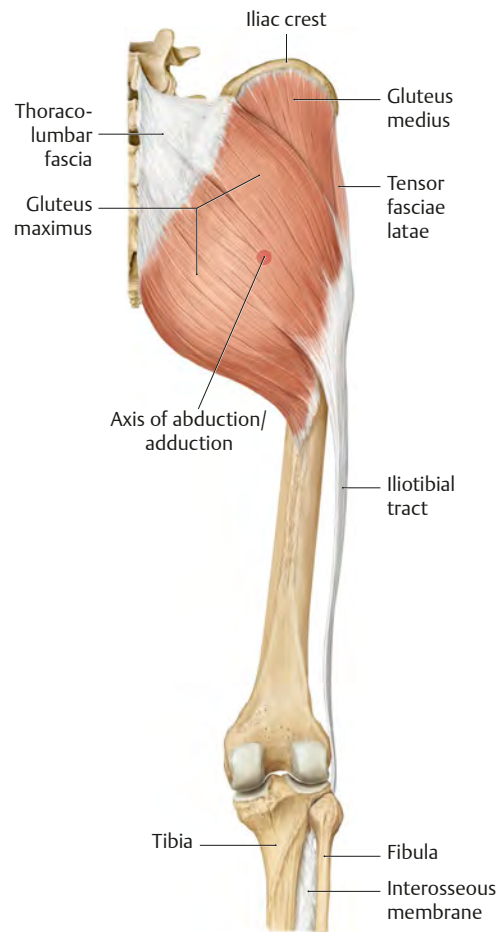
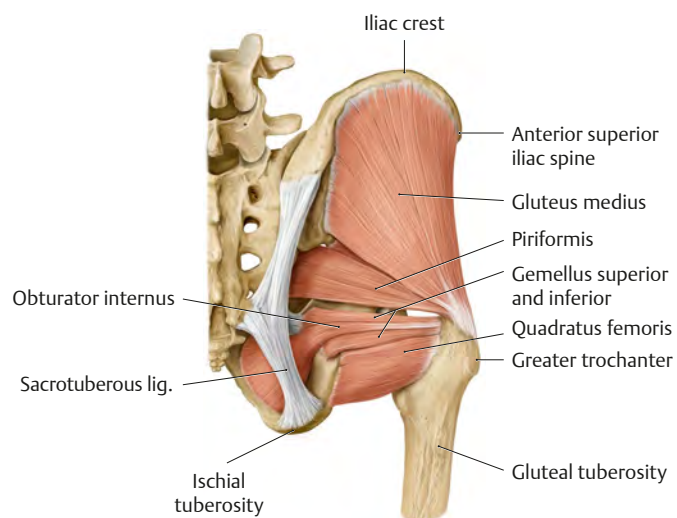
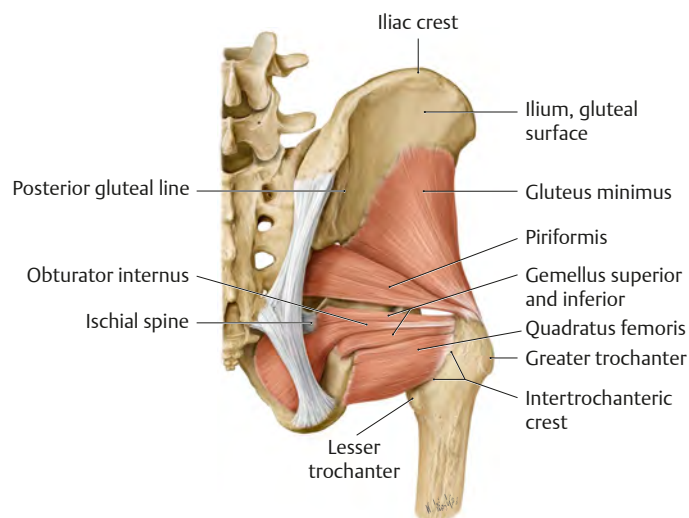


Fig. 31.21 Deep muscles of the gluteal region



A Deep layer with gluteus maximus removed.

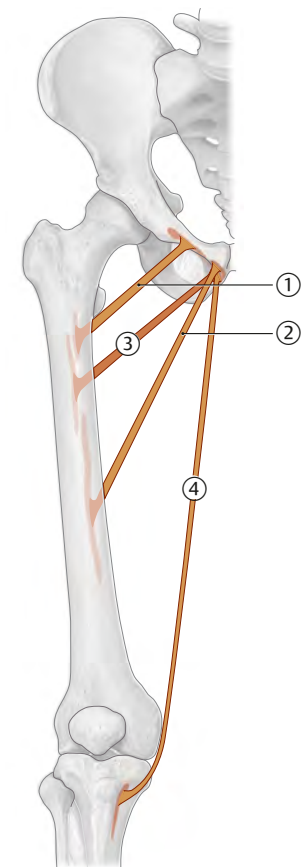


B Deep layer with gluteus maximus and gluteus medius removed.

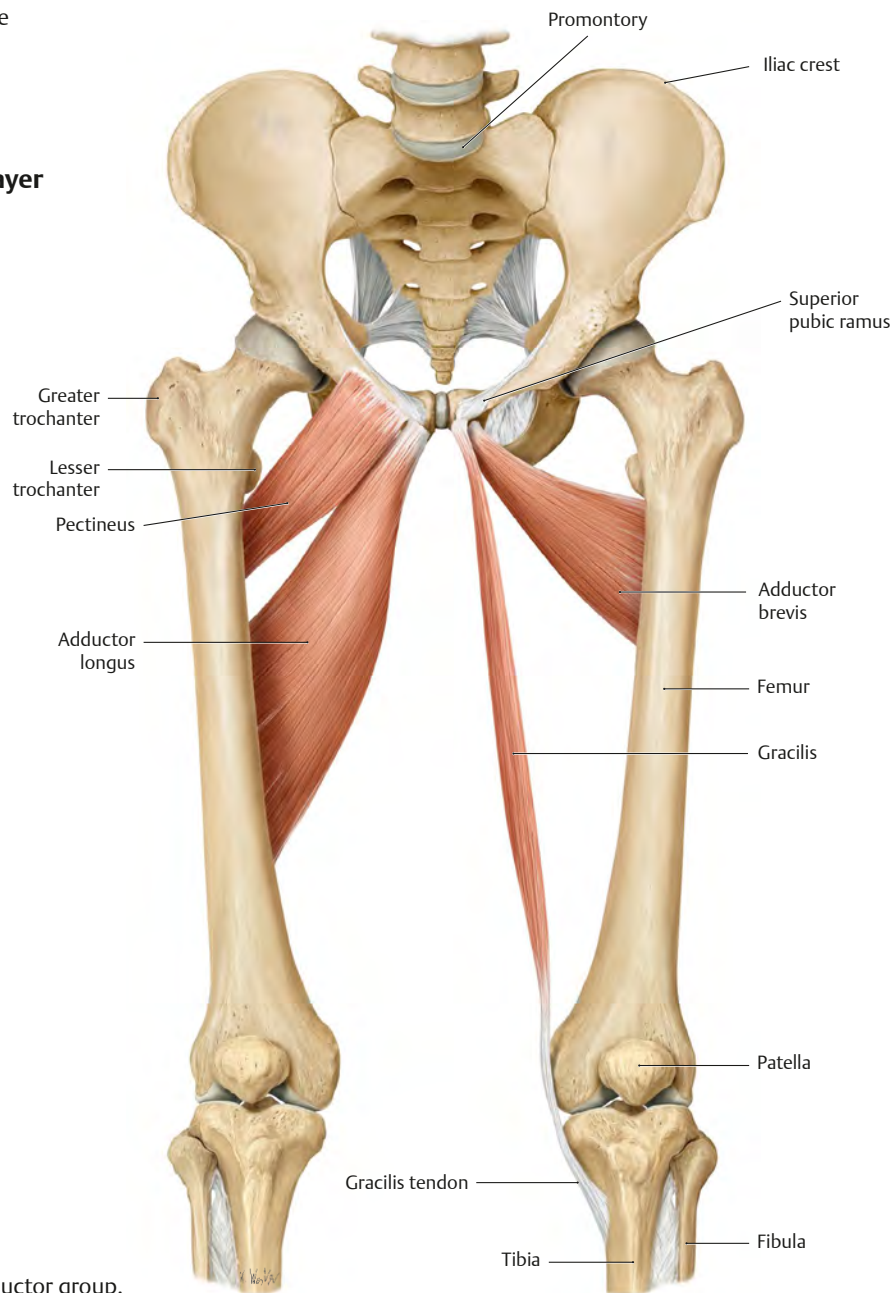
Muscle Facts (II)

Functionally, the medial thigh muscles are considered the adductors of the hip.

Fig. 31.22 Medial thigh muscles: Superficial layer
Right side, anterior view.



A Schematic.



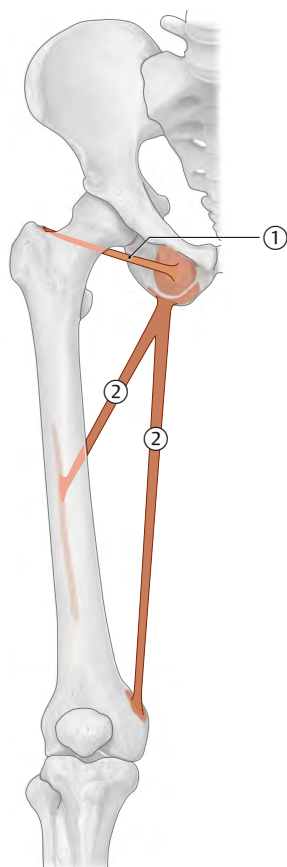
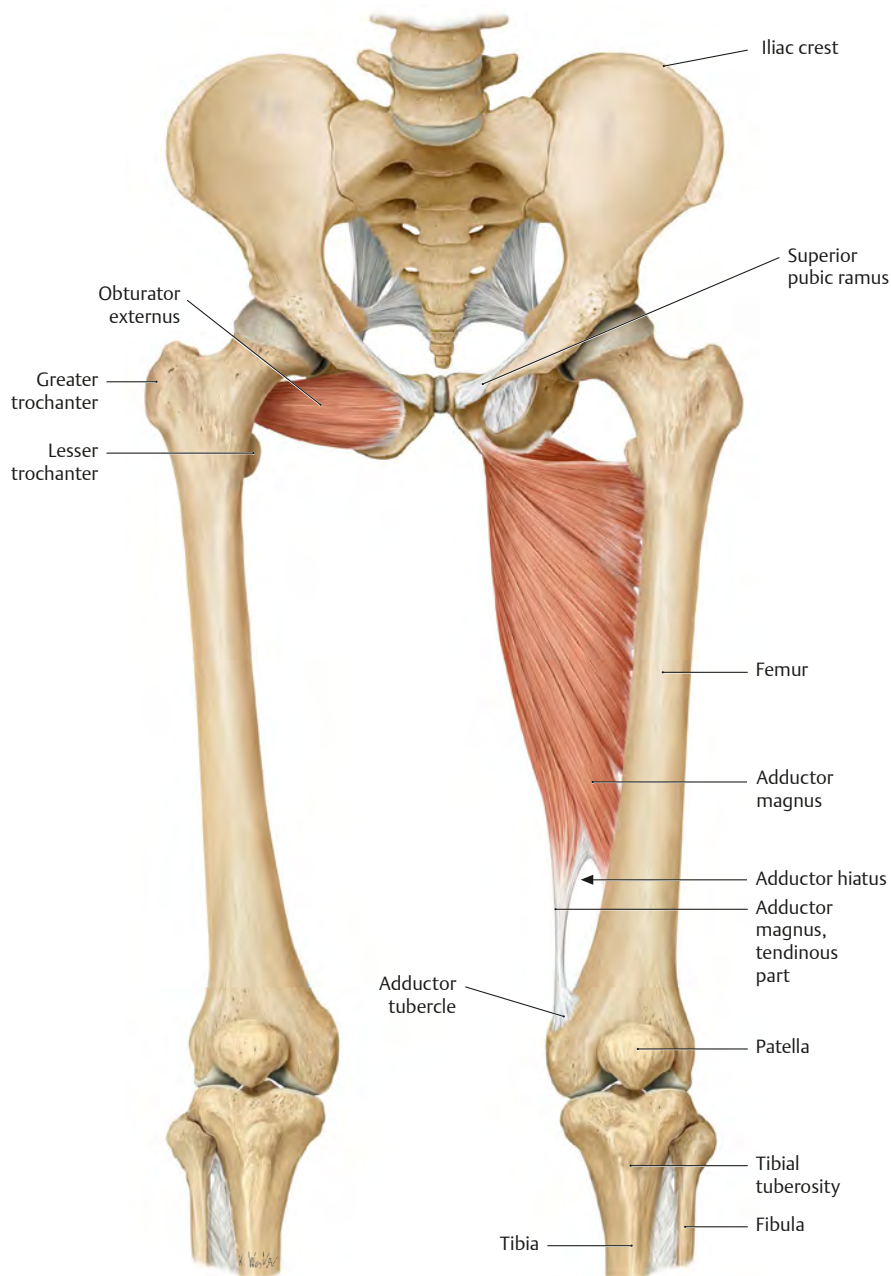
B Superficial adductor group.

Table 31.3 Medial thigh muscles: Superficial layer

Muscle	Origin	Insertion	Innervation	Action
① Pectineus	Pecten pubis	Femur (pectineal line and the proximal linea aspera)	Femoral n., obturator n. (L2, L3)	- Hip joint: adduction, external rotation, and slight flexion - Stabilizes the pelvis in the coronal and sagittal planes
② Adductor longus	Superior pubic ramus and anterior side of the pubic symphysis	Femur (linea aspera, medial lip in the middle third of the femur)	Obturator n. (L2–L4)	- Hip joint: adduction and flexion (up to 70 degrees); extension (past 80 degrees of flexion) - Stabilizes the pelvis in the coronal and sagittal planes
③ Adductor brevis	Inferior pubic ramus			
④ Gracilis	Inferior pubic ramus below the pubic symphysis	Tibia (medial border of the tuberosity, along with the tendons of sartorius and semitendinosus)	Obturator n. (L2, L3)	- Hip joint: adduction and flexion - Knee joint: flexion and internal rotation

Fig. 31.23 Medial thigh muscles: Deep layer

Right side, anterior view.

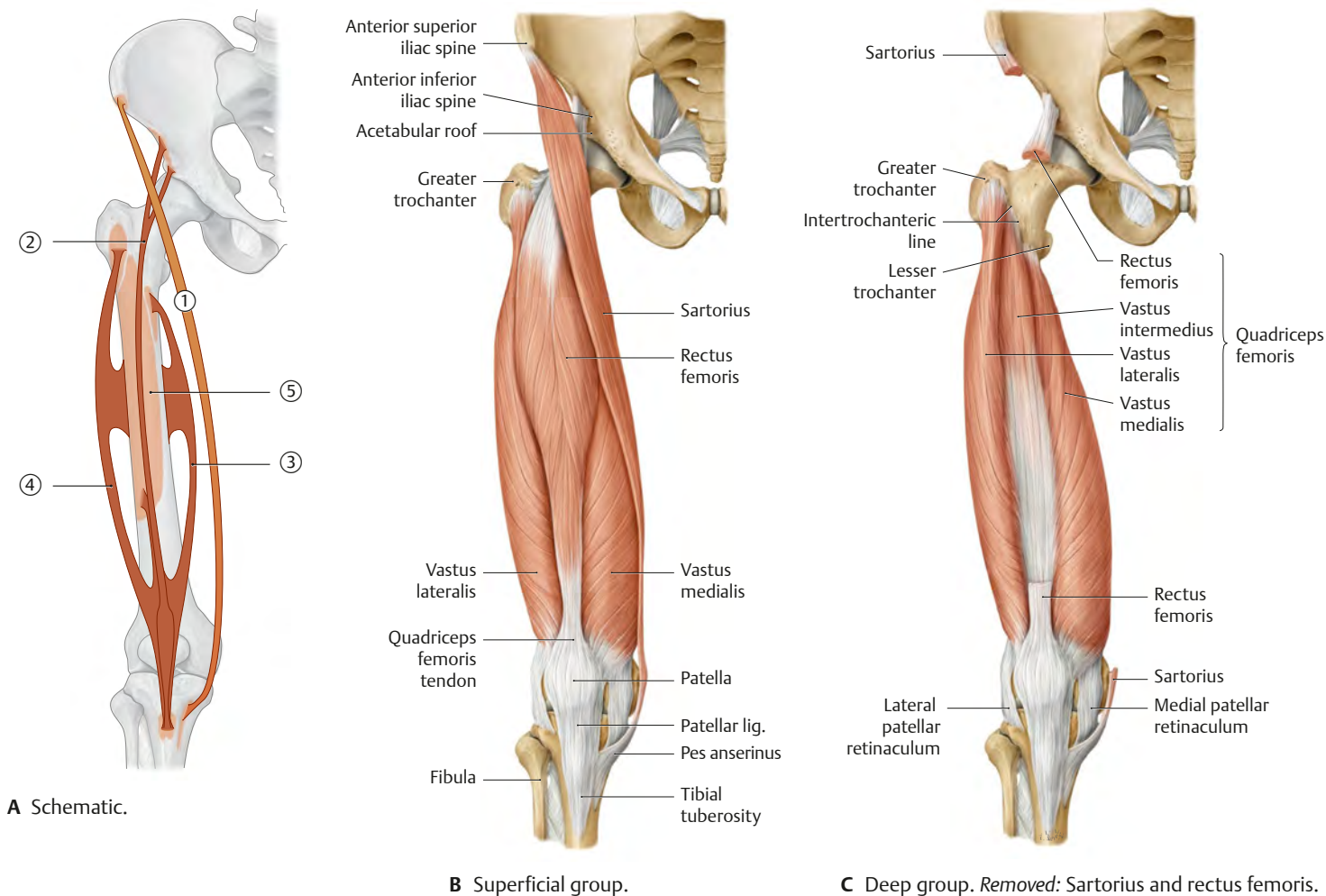
**A** Schematic.**B** Deep adductor group.**Table 31.4****Medial thigh muscles: Deep layer**

Muscle	Origin	Insertion	Innervation	Action
① Obturator externus	Outer surface of the obturator foramen and its bony boundaries	Trochanteric fossa of the femur	Obturator n. (L3, L4)	- Hip joint: adduction and external rotation - Stabilizes the pelvis in the sagittal plane
② Adductor magnus	Inferior pubic ramus, ischial ramus, and ischial tuberosity	- Deep part ("fleshy insertion"): medial lip of the linea aspera - Superficial part ("tendinous insertion"): adductor tubercle of the femur	- Deep part: obturator n. (L2–L4) - Superficial part: tibial n. (L4)	- Hip joint: adduction, extension, and slight flexion (the tendinous insertion is also active in internal rotation) - Stabilizes the pelvis in the coronal and sagittal planes

Muscle Facts (III)

The anterior and posterior muscles of the thigh can be classified as extensors and flexors, respectively, with regard to the knee joint.

Fig. 31.24 Anterior thigh muscles
Right side, anterior view.

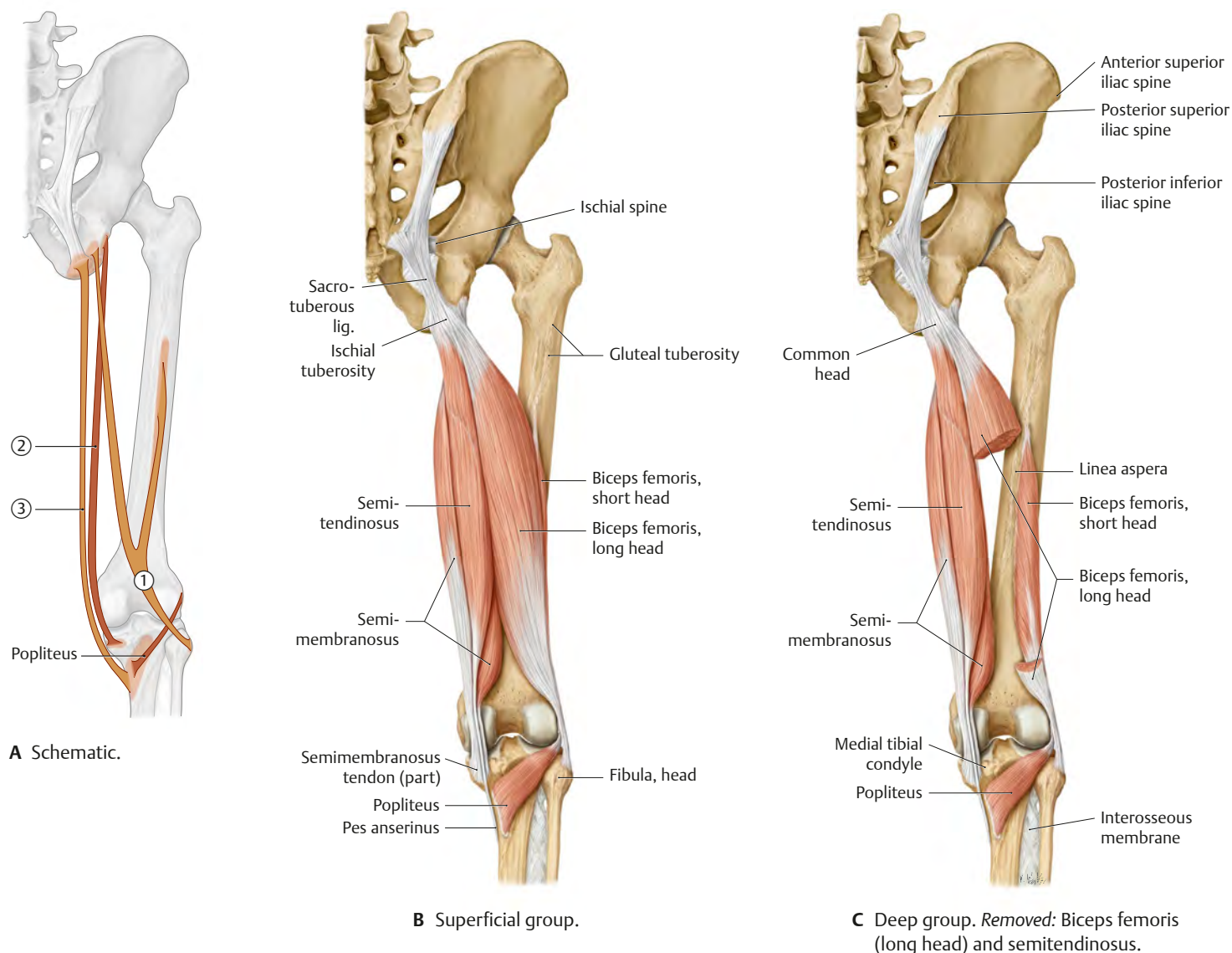


Muscle	Origin	Insertion	Innervation	Action
① Sartorius	Anterior superior iliac spine	Medial to the tibial tuberosity (together with gracilis and semitendinosus)	Femoral n. (L2, L3)	- Hip joint: flexion, abduction, and external rotation - Knee joint: flexion and internal rotation
Quadriceps femoris*	② Rectus femoris	Anterior inferior iliac spine, acetabular roof of hip joint	Femoral n. (L2–L4)	- Hip joint: flexion - Knee joint: extension
	③ Vastus medialis	Linea aspera (medial lip), intertrochanteric line (distal part)		Knee joint: extension
	④ Vastus lateralis	Linea aspera (lateral lip), greater trochanter (lateral surface)		
	⑤ Vastus intermedius	Femoral shaft (anterior side)		
	Articularis genus (distal fibers of vastus intermedius)	Anterior side of femoral shaft at level of the suprapatellar recess		Knee joint: extension; retracts the suprapatellar bursa to prevent entrapment of capsule

*The entire muscle inserts on the tibial tuberosity via the patellar lig.

Fig. 31.25 Posterior thigh muscles

Right side, posterior view.

**Table 31.6****Posterior thigh muscles**

Muscle	Origin	Insertion	Innervation	Action
① Biceps femoris	Long head: ischial tuberosity, sacrotuberous lig. (common head with semitendinosus)	Head of fibula	Tibial n. (L5–S2)	- Hip joint (long head): extends the hip, stabilizes the pelvis in the sagittal plane - Knee joint: flexion and external rotation
	Short head: lateral lip of the linea aspera in the middle third of the femur		Common fibular n. (L5–S2)	Knee joint: flexion and external rotation
② Semimembranosus	Ischial tuberosity	Medial tibial condyle, oblique popliteal lig., popliteus fascia	Tibial n. (L5–S2)	Hip joint: extends the hip, stabilizes the pelvis in the sagittal plane
③ Semitendinosus	Ischial tuberosity and sacrotuberous lig. (common head with long head of biceps femoris)	Medial to the tibial tuberosity in the pes anserinus (along with the tendons of gracilis and sartorius)		Knee joint: flexion and internal rotation

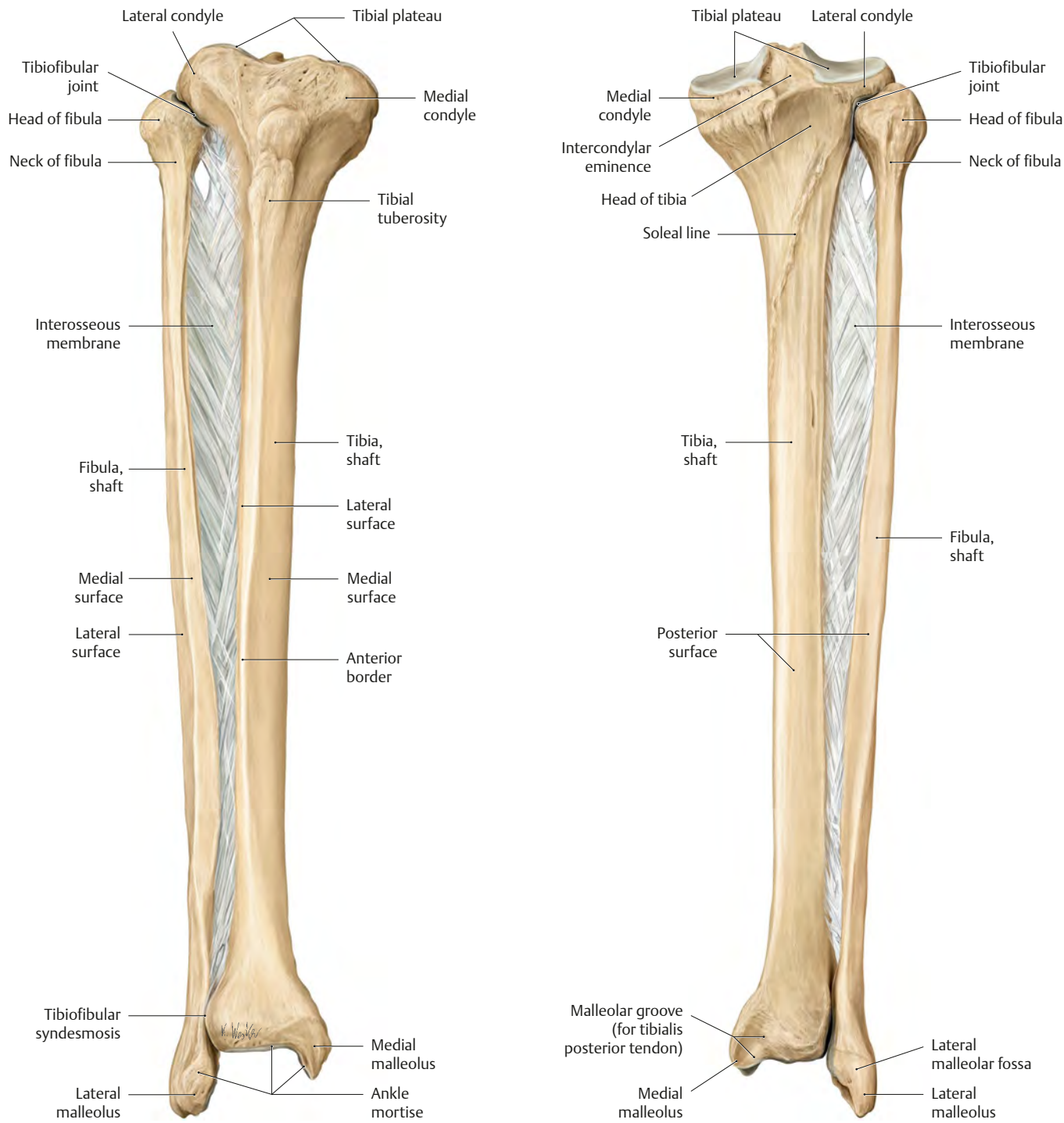
See p. 451 for the popliteus.

32 Knee & Leg

Tibia & Fibula

The tibia and fibula articulate at two joints, allowing limited motion (rotation). The crural interosseous membrane is a sheet of tough connective tissue that serves as an origin for several muscles in the leg. It also acts with the tibiofibular syndesmosis to stabilize the ankle joint.

Fig. 32.1 Tibia and fibula
Right leg.



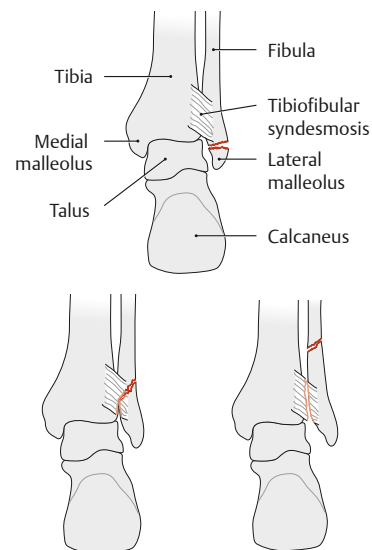
A Anterior view.

B Posterior view.

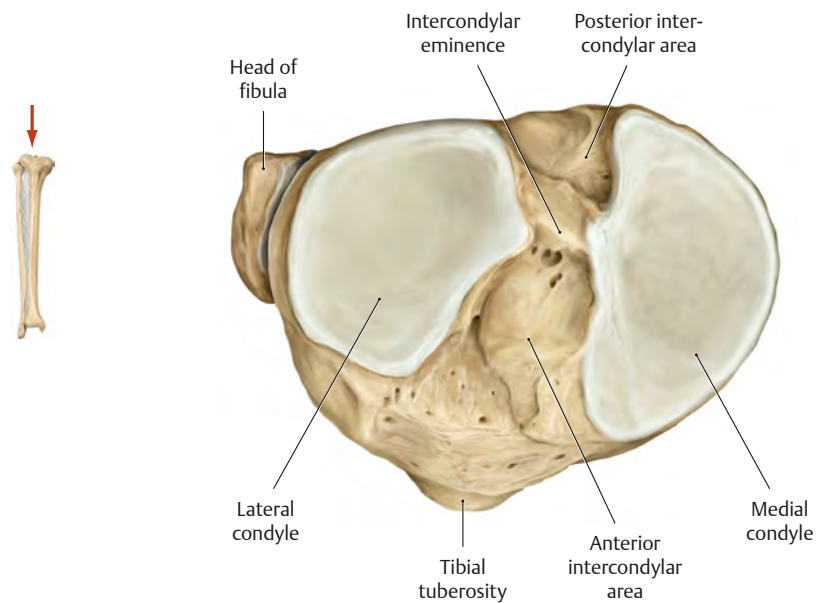
Clinical box 32.1

Fibular fracture

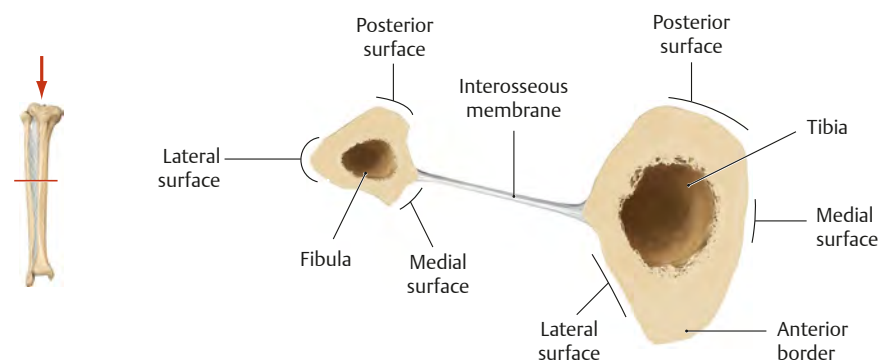
When diagnosing a fibular fracture, it is important to determine whether the tibiofibular syndesmosis (see p. 432) is disrupted. Fibular fractures may occur distal to, level with, or proximal to the tibiofibular syndesmosis; the latter two frequently involve tearing of the syndesmosis.



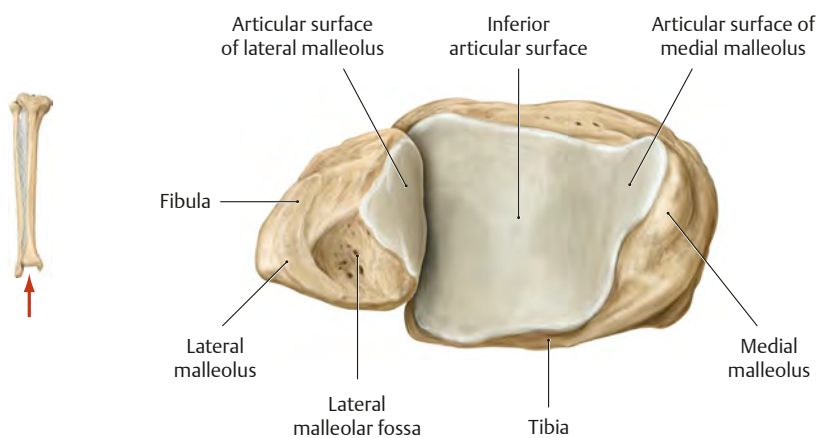
In this fracture located proximal to the syndesmosis (arrow), the syndesmosis is torn, as indicated by the widened medial joint space of the upper ankle joint (see pp. 456–457).



C Proximal view.



D Transverse section, proximal view.



E Distal view.

Knee Joint: Overview

In the knee joint, the femur articulates with the tibia and patella. Both joints are contained within a common capsule and have communicating articular cavities. *Note:* The fibula is not included in the knee joint

(contrast to the humerus in the elbow; see **p. 326**). Instead, it forms a separate rigid articulation with the tibia.

Fig. 32.2 Right knee joint

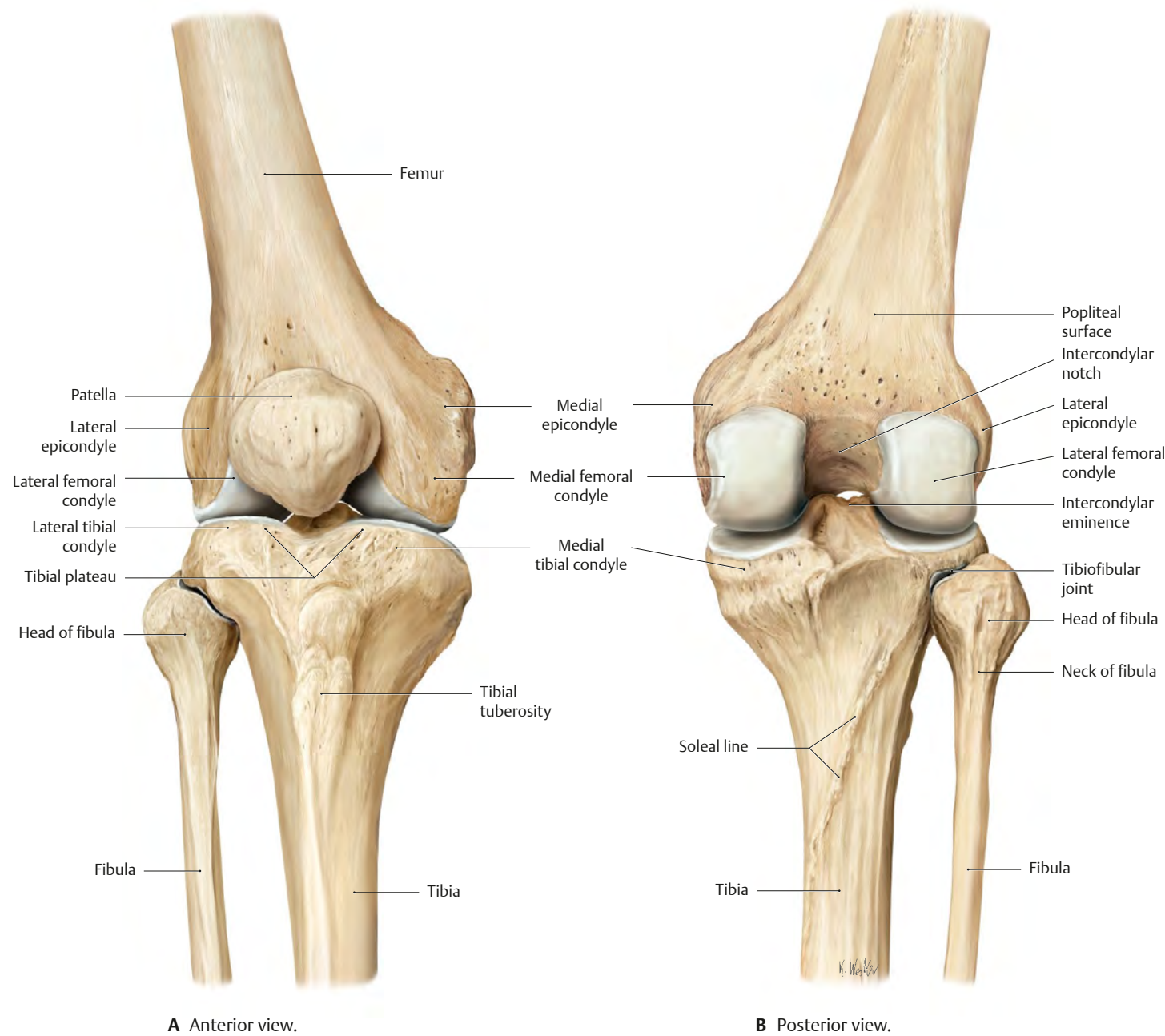
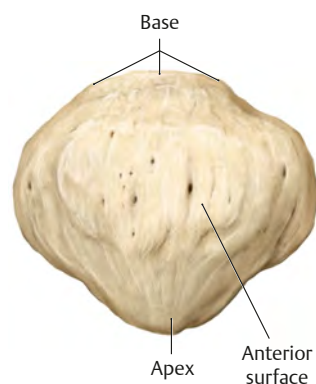
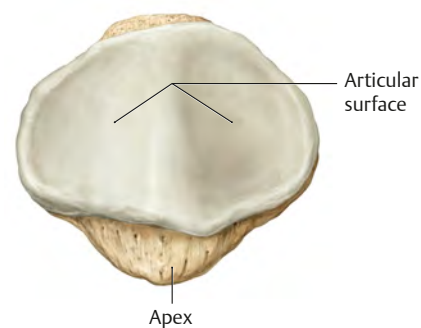
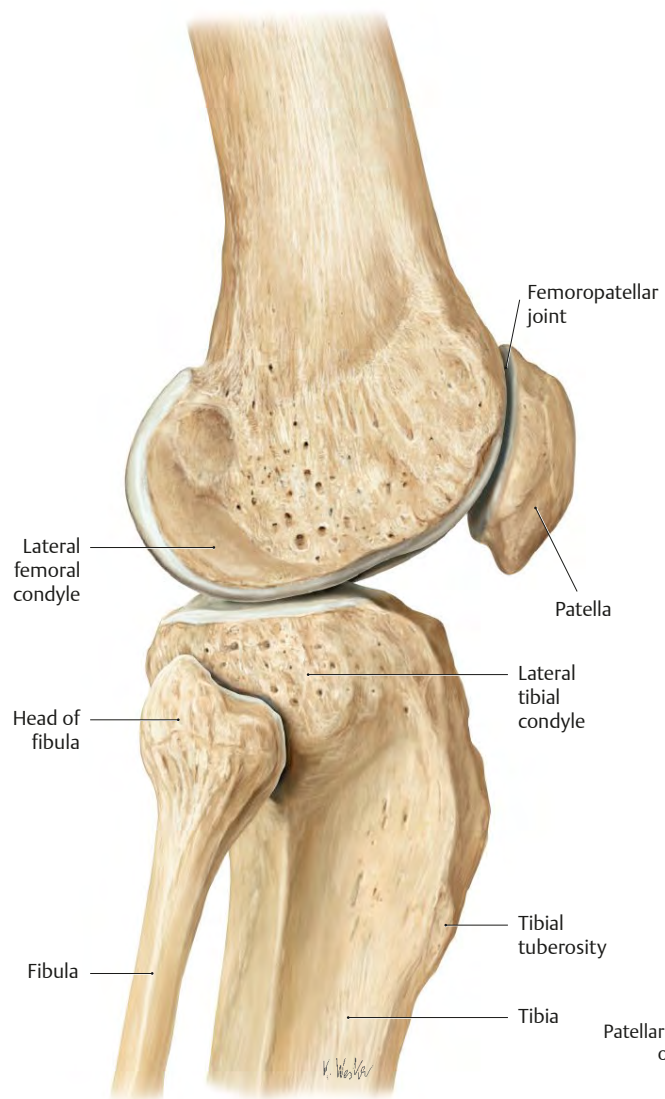
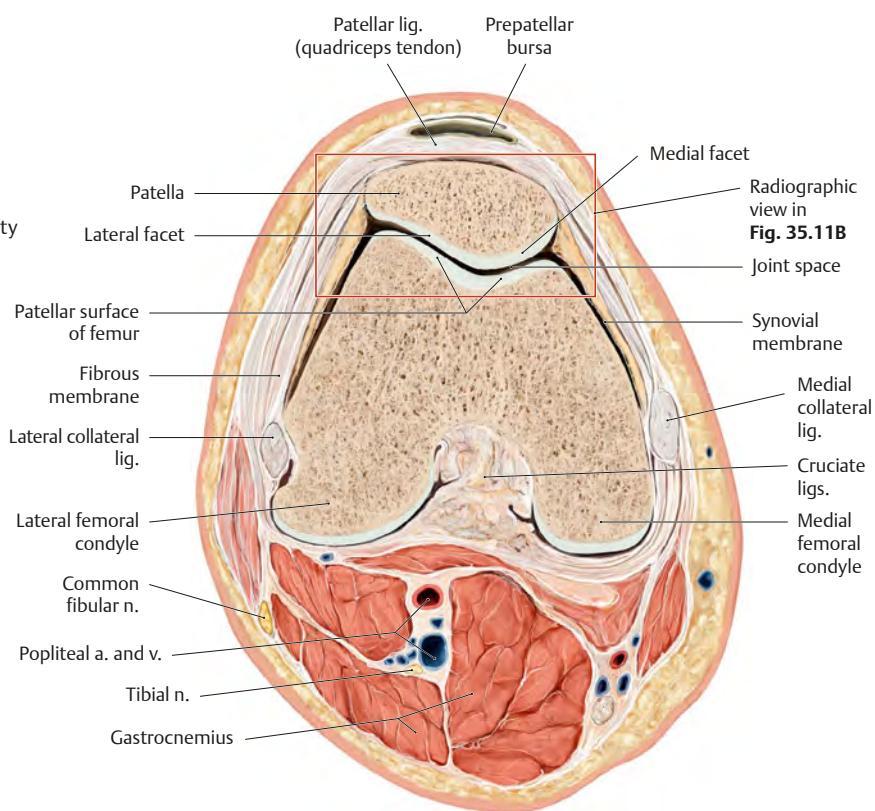


Fig. 32.3 Patella**A Anterior view.****B Posterior view.****C Lateral view.****Fig. 32.4 Patellofemoral joint: Transverse section**

Distal view with right knee in slight flexion.



Knee Joint: Capsule, Ligaments & Bursae

Table 32.1	Ligaments of the knee joint
Extrinsic ligaments	
Anterior side	Patellar lig.
	Medial longitudinal patellar retinaculum
	Lateral longitudinal patellar retinaculum
	Medial transverse patellar retinaculum
	Lateral transverse patellar retinaculum
Medial and lateral sides	Medial (tibial) collateral lig.
	Lateral (fibular) collateral lig.
Posterior side	Oblique popliteal lig.
	Arcuate popliteal lig.
Intrinsic ligaments	
Anterior cruciate lig.	
Posterior cruciate lig.	
Transverse lig. of knee	
Posterior meniscomfemoral lig.	

Fig. 32.5 Ligaments of the knee joint
Anterior view of right knee.

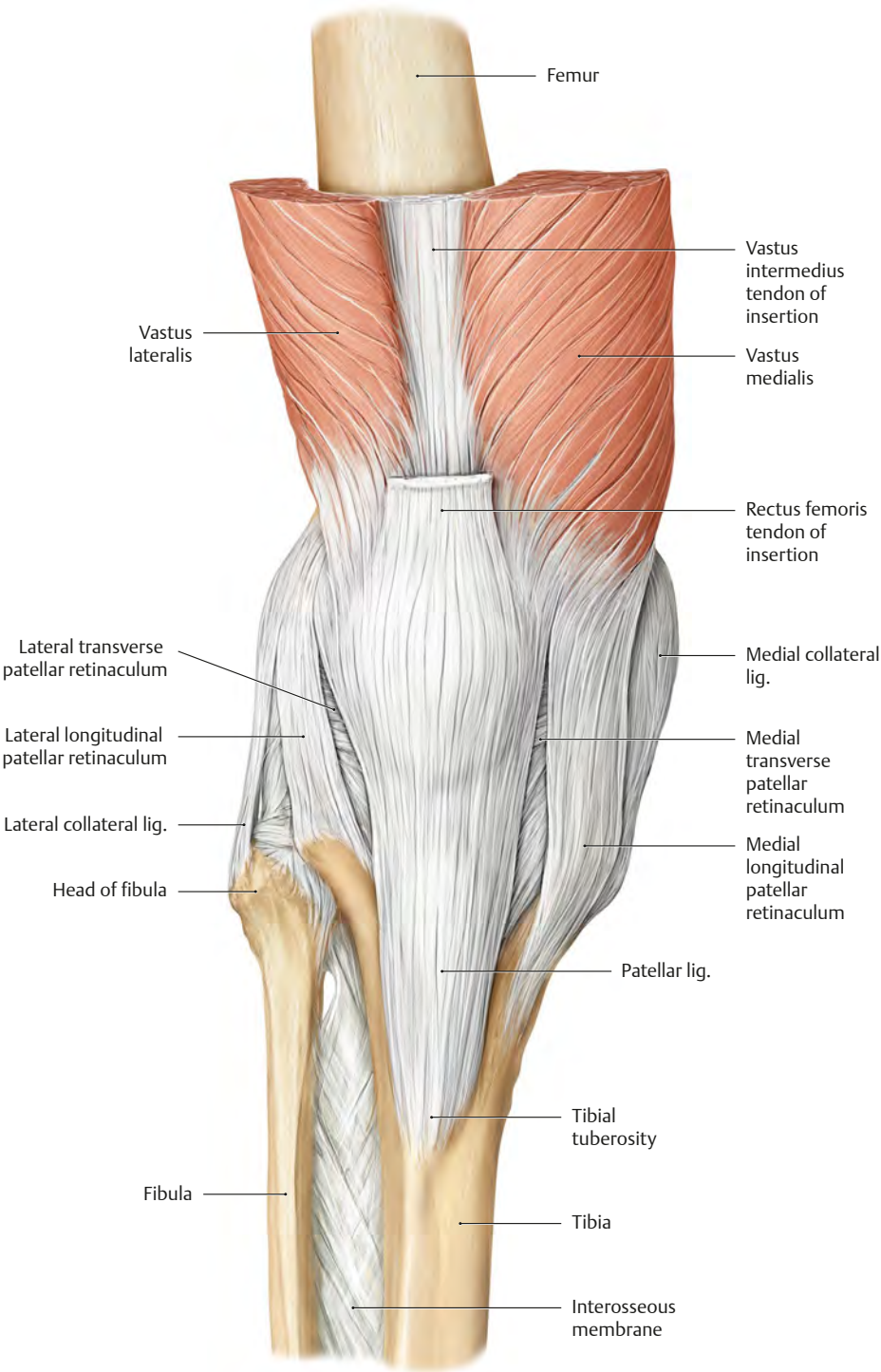
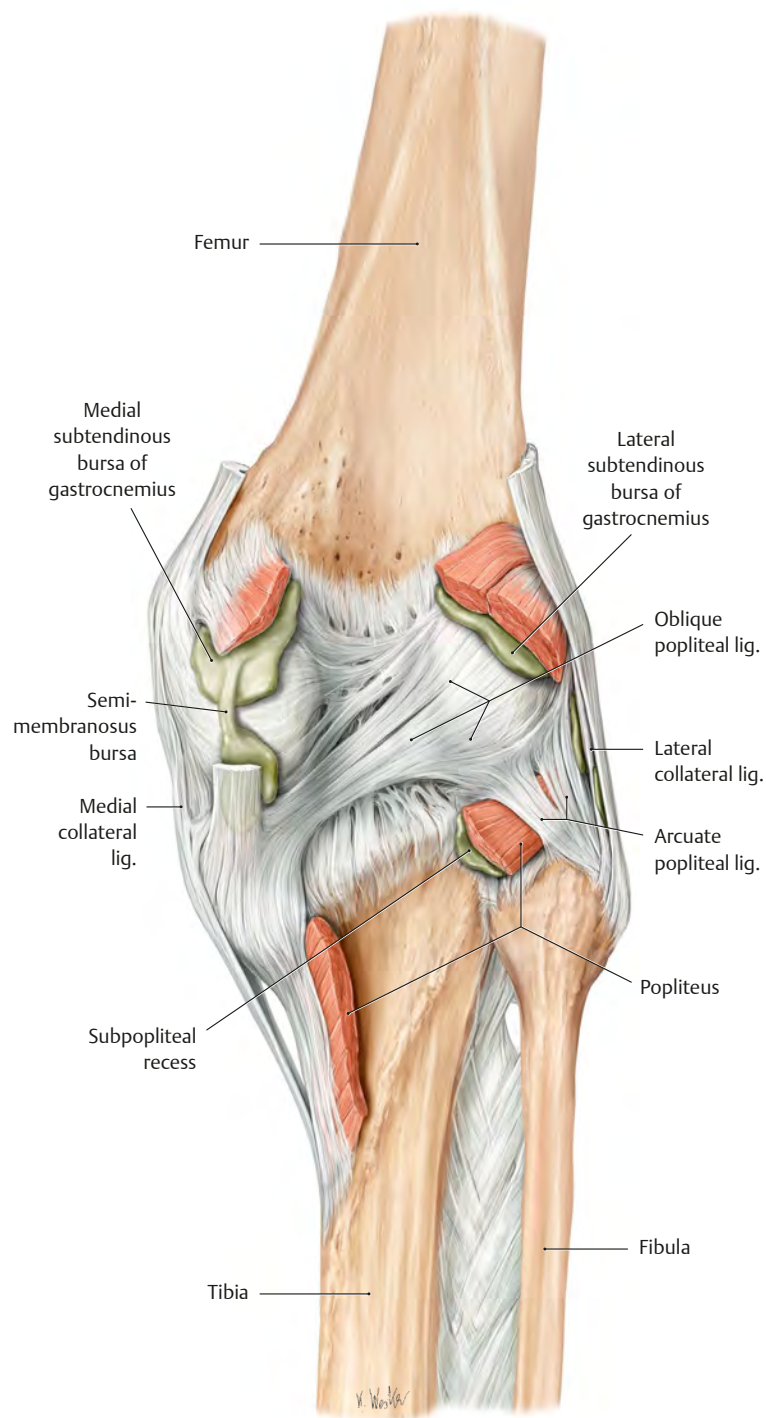
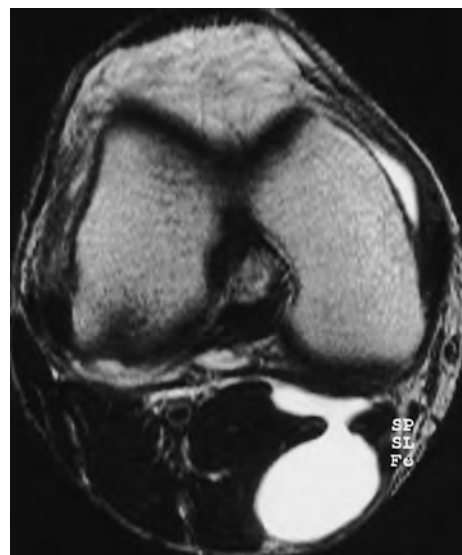


Fig. 32.6 Capsule, ligaments, and periarticular bursae

Posterior view of right knee. The joint cavity communicates with peri-articular bursae at the subpopliteal recess, semimembranosus bursa, and medial subtendinous bursa of the gastrocnemius.

**Clinical box 32.2****Gastrocnemio-semimembranosus bursa (Baker's cyst)**

Painful swelling behind the knee may be caused by a cystic outpouching of the joint capsule (synovial popliteal cyst). This frequently results from an increase in intra-articular pressure (e.g., in rheumatoid arthritis).



Axial MRI of a Baker's cyst in the right popliteal fossa, inferior view. Baker's cysts often occur in the medial part of the popliteal fossa between the semimembranosus tendon and the medial head of the gastrocnemius at the level of the posteromedial femoral condyle.

Knee Joint: Ligaments & Menisci

Fig. 32.7 Collateral and patellar ligaments of the knee joint

Right knee joint. Each knee joint has medial and lateral collateral ligaments. The medial collateral ligament is attached to both the capsule and the medial meniscus, whereas the lateral collateral ligament has no

direct contact with either the capsule or the lateral meniscus. Both collateral ligaments are taut when the knee is in extension and stabilize the joint in the coronal plane.

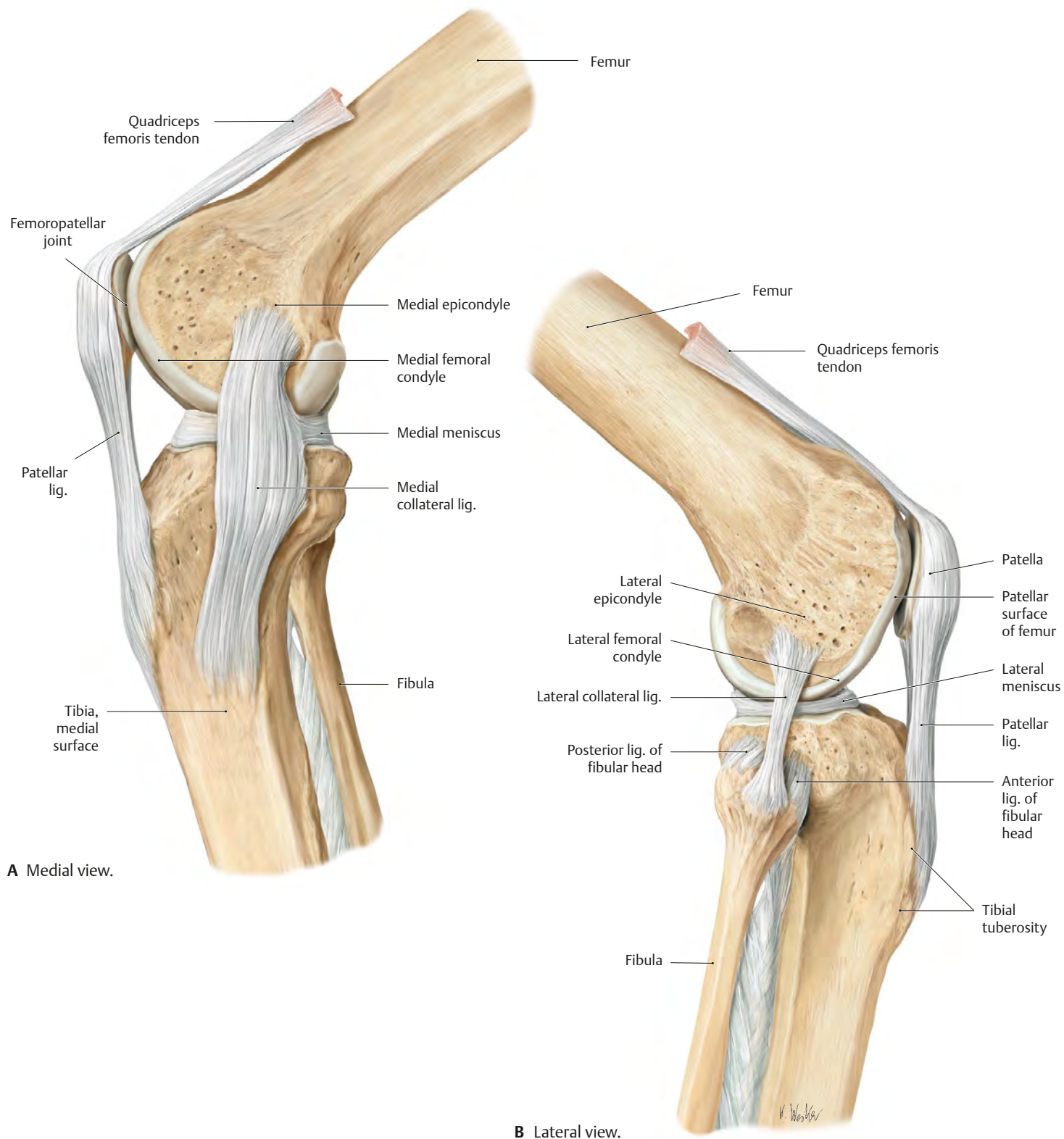
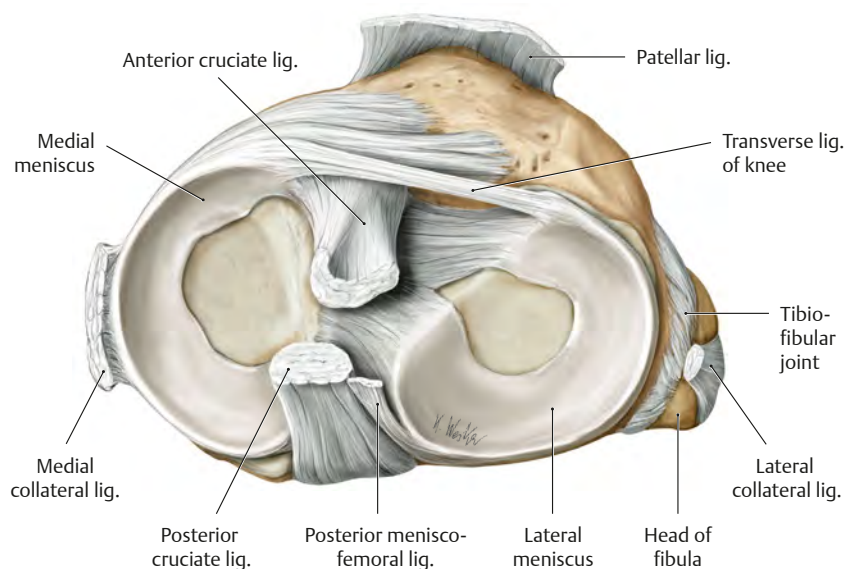
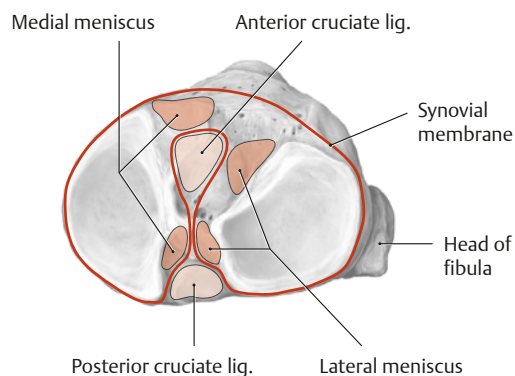


Fig. 32.8 Menisci in the knee joint

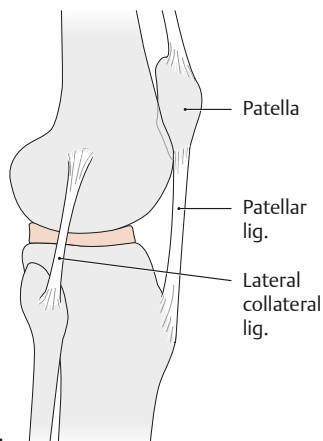
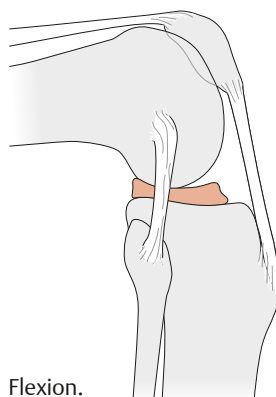
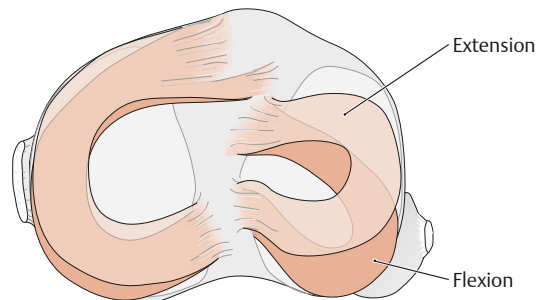
Right tibial plateau, proximal view.

**A** Right tibial plateau with cruciate, patellar, and collateral ligaments divided.**B** Attachment sites of menisci and cruciate ligaments. Red line indicates the tibial attachment of the synovial membrane that covers the cruciate ligaments. The cruciate ligaments lie in the subsynovial connective tissue.**Clinical box 32.3****Injury to the menisci**

The less mobile medial meniscus (see Fig. 32.9) is more susceptible to injury than the lateral meniscus. Trauma generally results from sudden extension or rotation of the flexed knee while the leg is fixed.

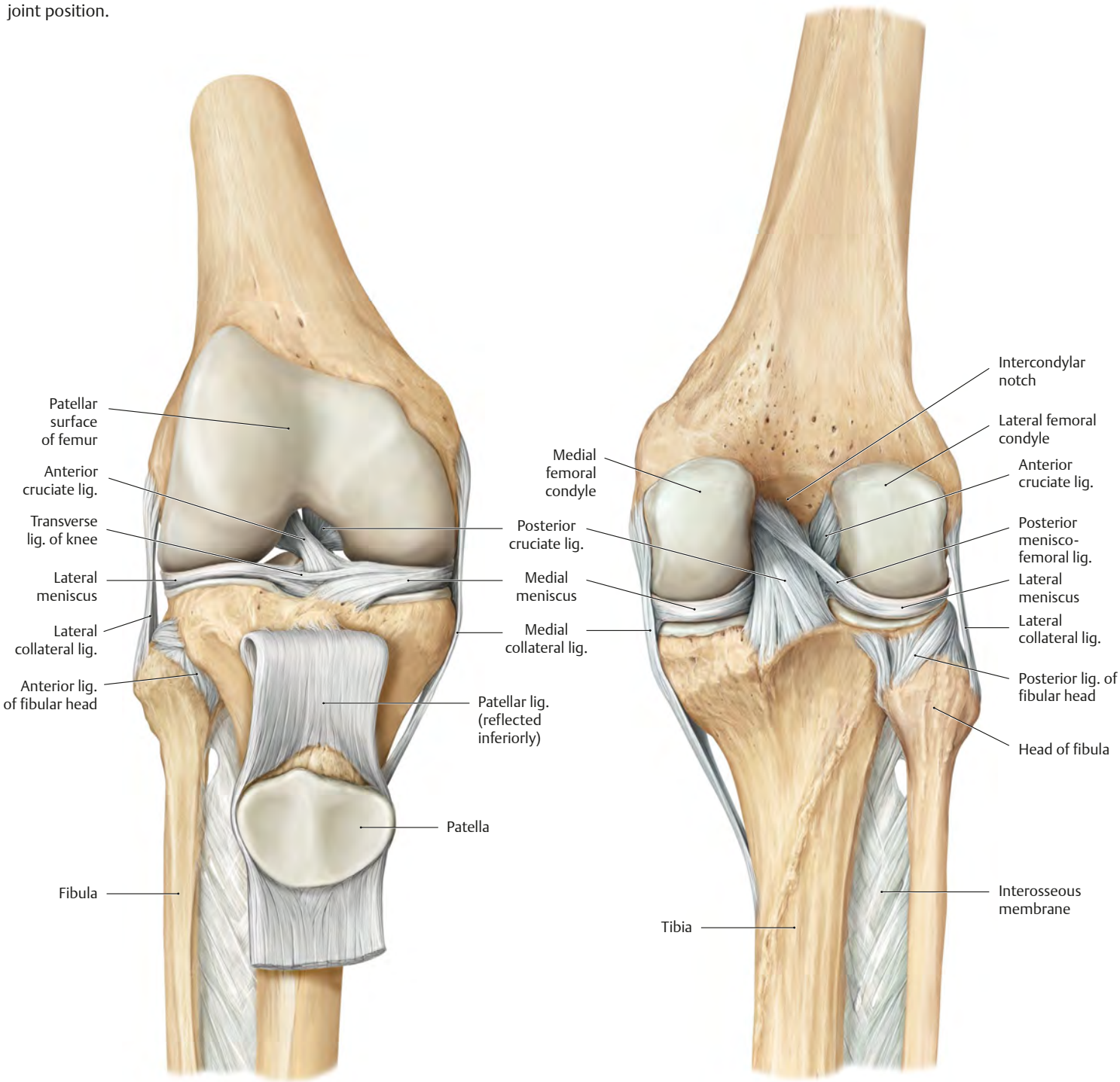
**A** Bucket-handle tear.**B** Radial tear of posterior horn.**Fig. 32.9 Movements of the menisci**

Right knee joint. The medial meniscus, which is anchored more securely than the lateral meniscus, undergoes less displacement during knee flexion.

**A** Extension.**B** Flexion.**C** Tibial plateau, proximal view.

Cruciate Ligaments

Fig. 32.10 Cruciate and collateral ligaments
Right knee joint. The cruciate ligaments keep the articular surfaces of the femur and tibia in contact, while stabilizing the knee joint primarily in the sagittal plane. Portions of the cruciate ligaments are taut in every joint position.



A Anterior view.

B Posterior view.

Fig. 32.11 Right knee joint in flexion
Anterior view with joint capsule and patella removed.

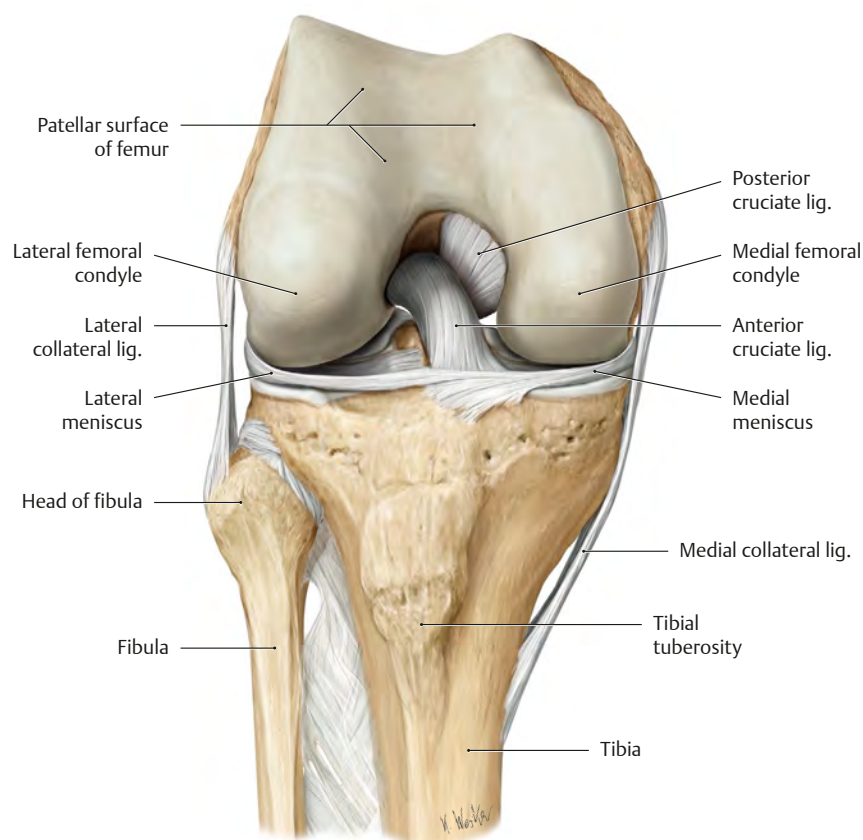
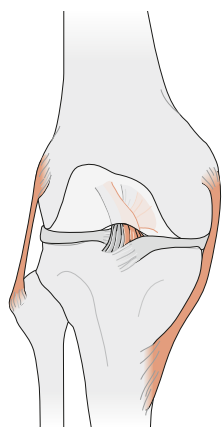
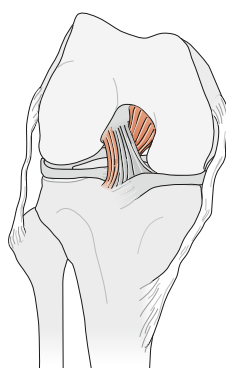


Fig. 32.12 Cruciate and collateral ligaments in flexion and extension

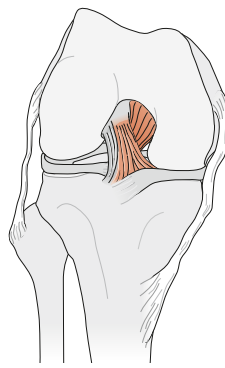
Right knee, anterior view. Taut ligament fibers shown in red. While most parts of the collateral ligaments are taut only in extension (A), the cruciate ligaments, or portions of them, are taut in flexion, extension and internal rotation (B,C). The cruciate ligaments thus help stabilize the knee in any joint position.



A Extension.



B Flexion.

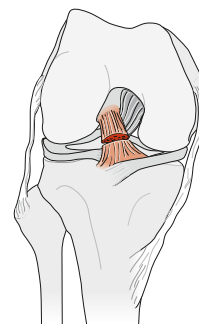


C Flexion and internal rotation.

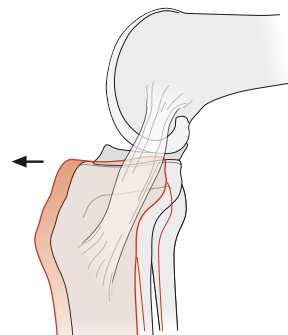
Clinical box 32.4

Rupture of cruciate ligaments

Cruciate ligament rupture destabilizes the knee joint, allowing the tibia to move forward (anterior “drawer sign”) or backward (posterior “drawer sign”) relative to the femur. Anterior cruciate ligament ruptures are approximately 10 times more common than posterior ligament ruptures. The most common mechanism of injury is an internal rotation trauma with the leg fixed. A lateral blow to the fully extended knee with the foot planted tends to cause concomitant rupture of the anterior cruciate and medial collateral ligaments, as well as tearing of the attached medial meniscus.



A Right knee in flexion, rupture of anterior cruciate ligament, anterior view.



B Right knee in flexion, anterior “drawer sign,” medial view. During examination of the flexed knee, the tibia can be pulled forward.

Knee Joint Cavity

Fig. 32.13 Opened joint capsule

Right knee, anterior view with patella reflected downward.

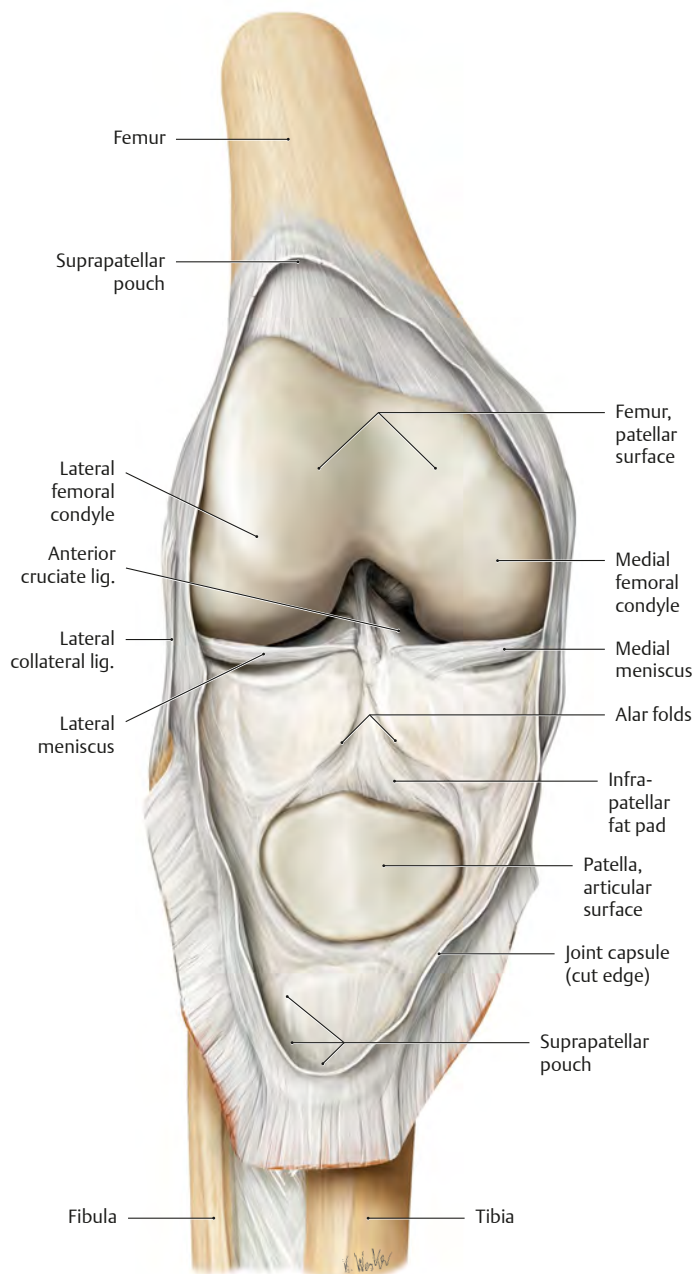


Fig. 32.14 Joint cavity

Right knee, lateral view. The joint cavity was demonstrated by injecting liquid plastic into the knee joint and later removing the capsule.

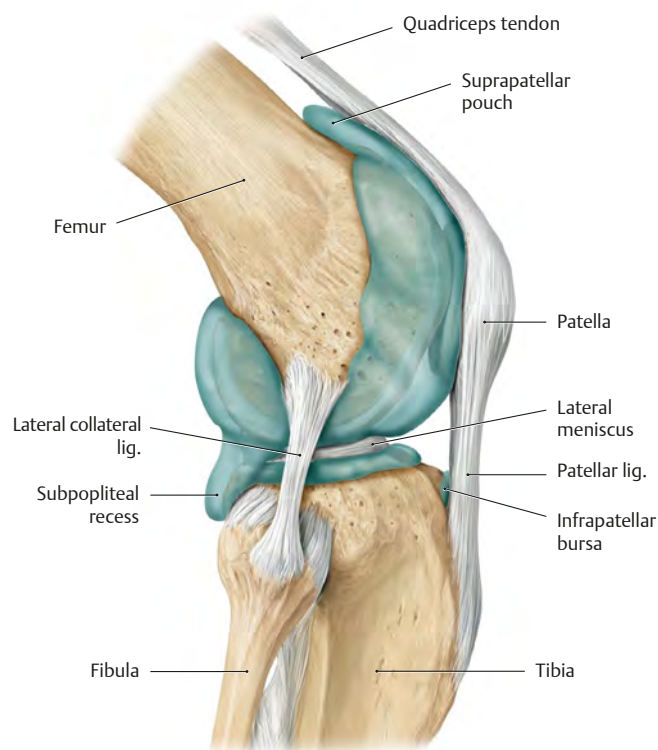


Fig 32.15 Relations of structures to the joint capsule and articular cavity

Right knee joint, proximal view.

Several joint structures provide strength or stability to the knee from outside of, or within, the joint space.

- Extracapsular structures (lateral collateral ligament) remain outside of the joint capsule.
- Intracapsular structures (medial collateral and cruciate ligaments) lie within the joint capsule but run in the subsynovial tissue outside the synovial membrane and are therefore also extra-articular.
- Intra-articular structures (menisci) lie within the articular cavity, enclosed by the synovial membrane, and are bathed in synovial fluid.

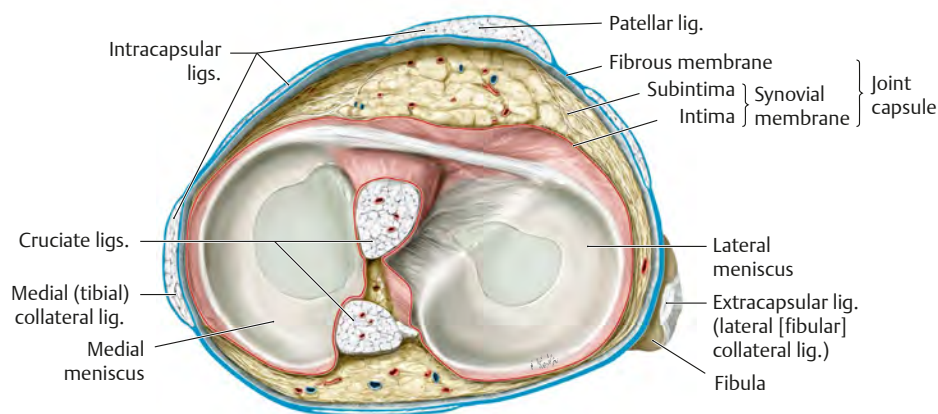


Fig. 32.16 Right knee joint: Midsagittal section
Lateral view.

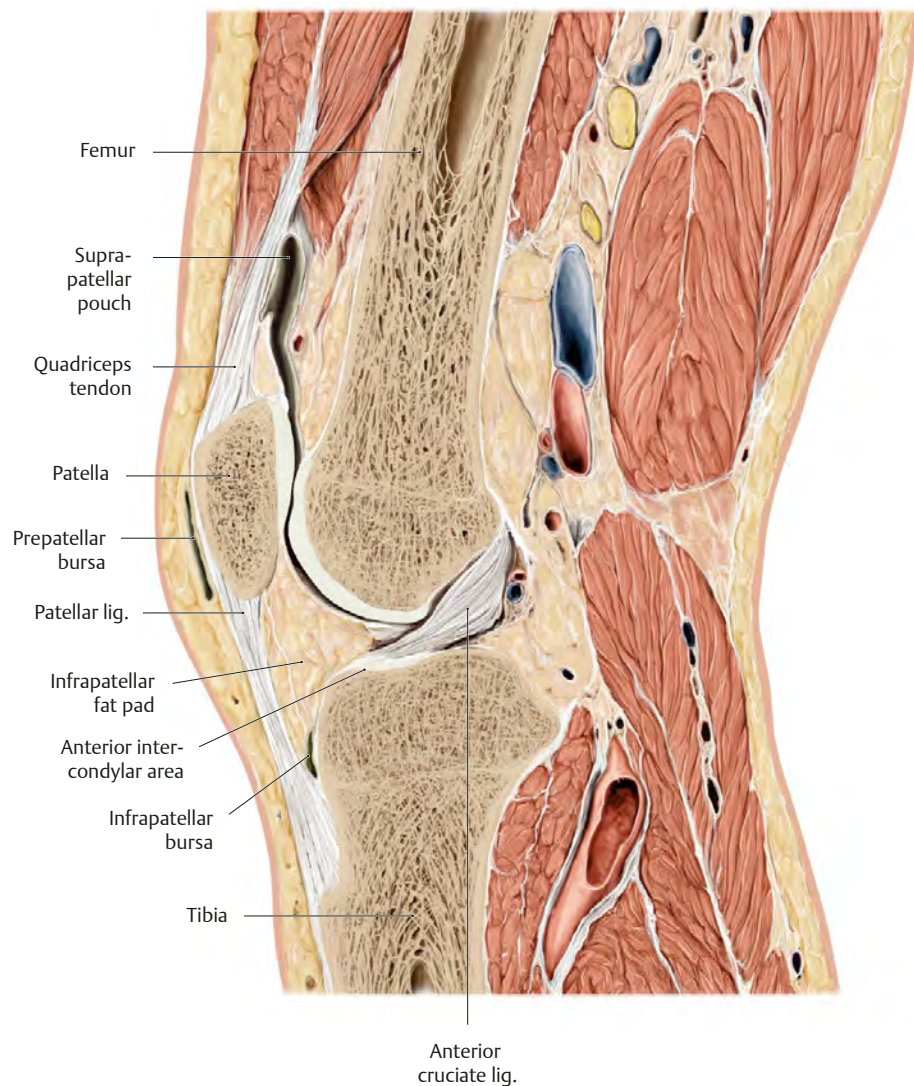
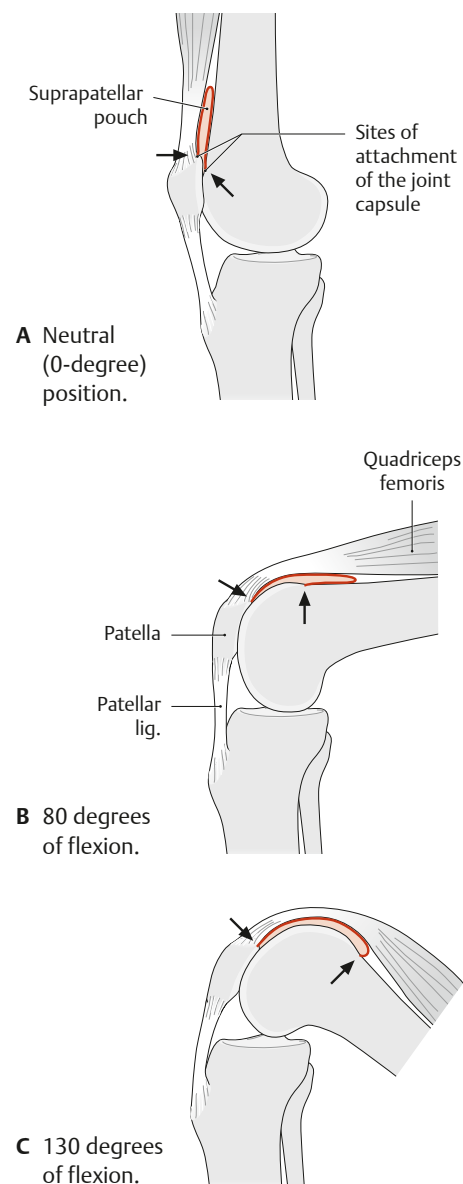


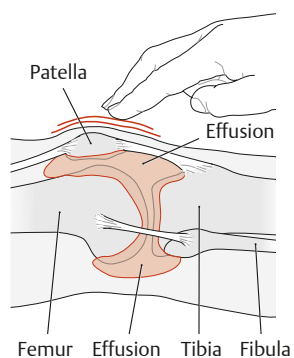
Fig. 32.17 Suprapatellar pouch during flexion
Right knee joint, medial view.



Clinical box 32.5

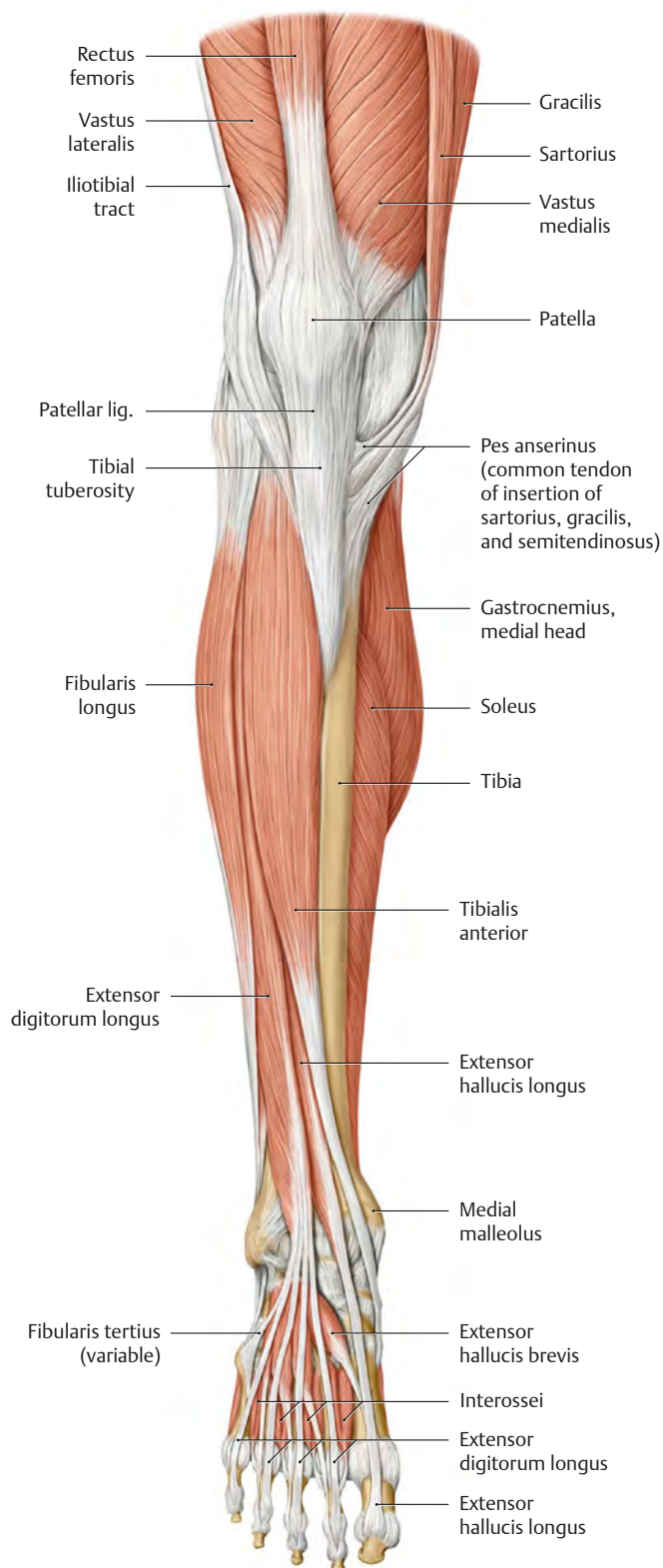
The ballottable patella sign of knee effusion

Intra-articular effusion due to inflammatory changes or injury can be differentiated from swelling of the joint capsule by pushing down on the patella of the extended knee. If there is excessive fluid in the joint, the patella will rebound when released, signifying a positive test.

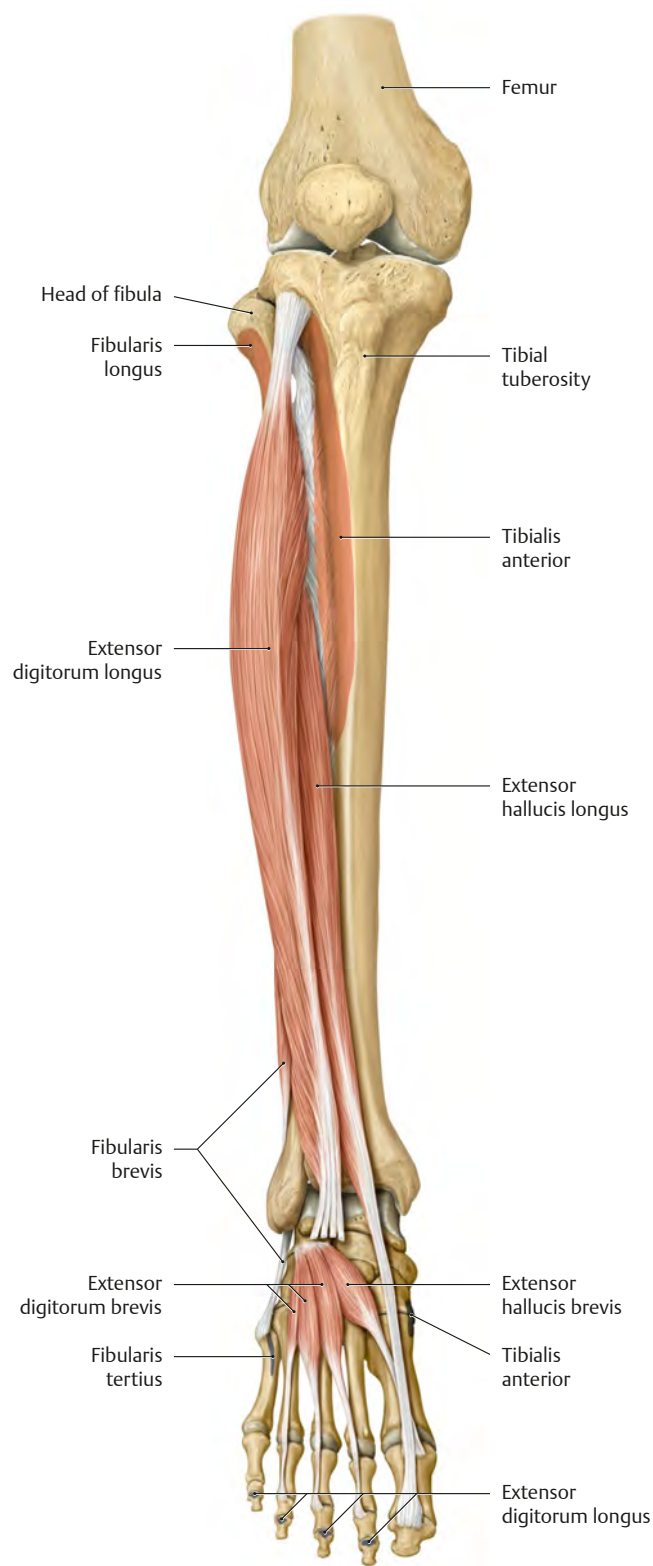


Muscles of the Leg: Anterior & Lateral Compartments

Fig. 32.18 Muscles of the anterior compartment of the leg
Right leg. Muscle origins shown in red, insertions in blue.

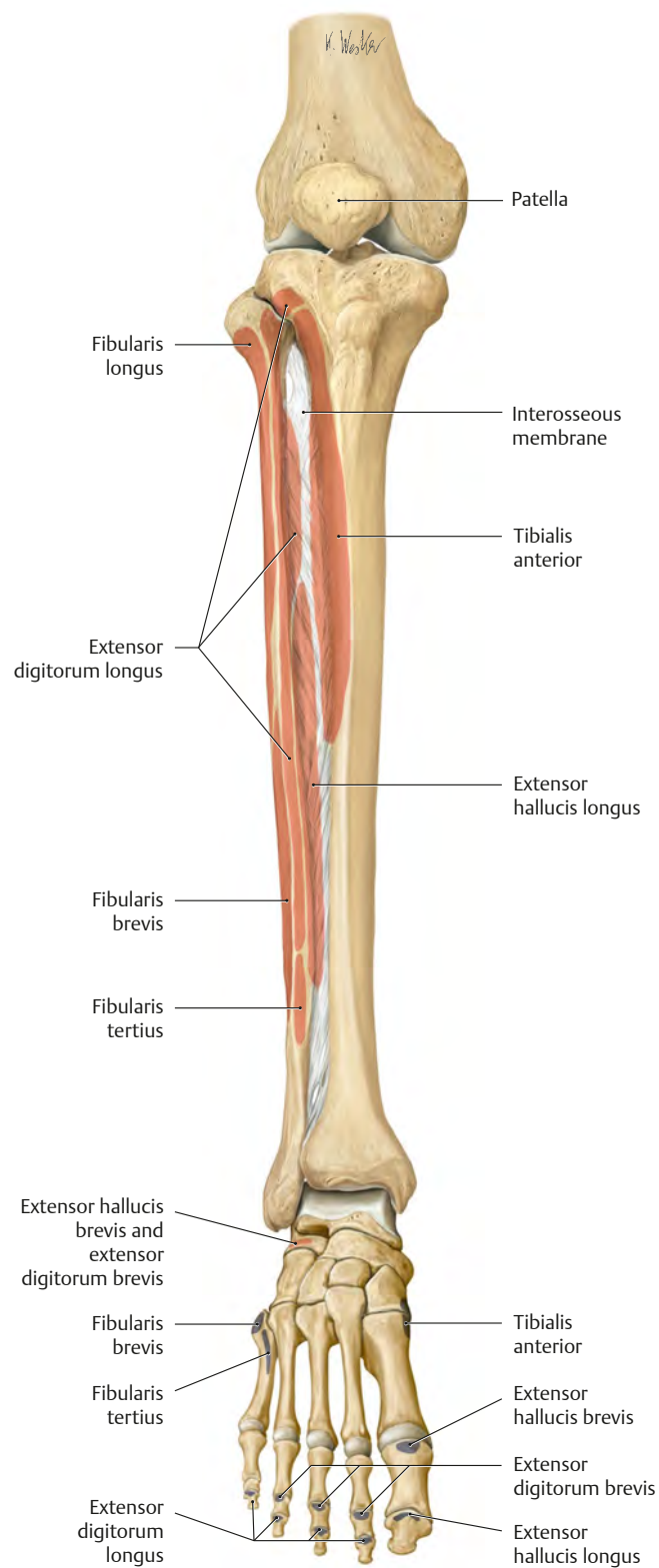


A All muscles shown.

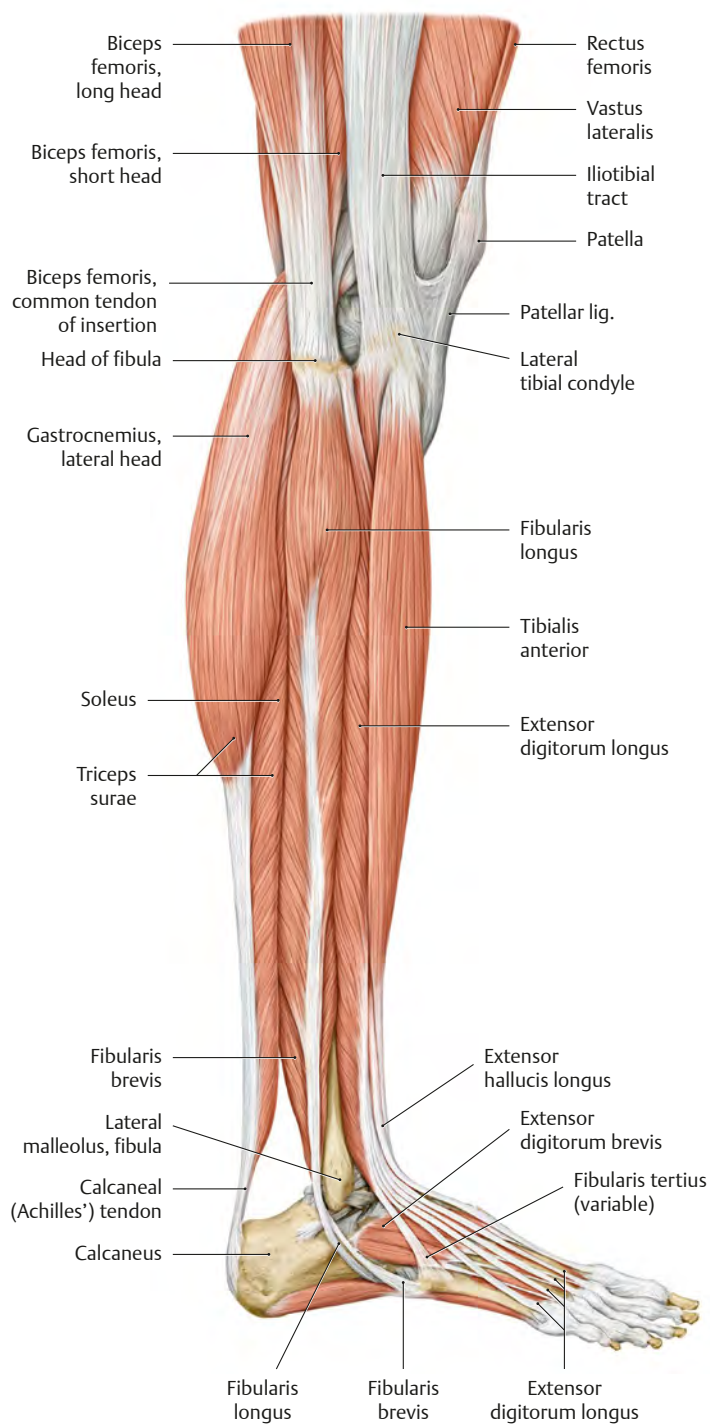


B Removed: Tibialis anterior and fibularis longus; extensor digitorum longus tendons (distal portions). Note: The fibularis tertius is a division of the extensor digitorum longus.

Fig. 32.19 Muscles of the lateral compartment of the leg
Right leg. The triceps surae is comprised of the soleus and two heads of the gastrocnemius.

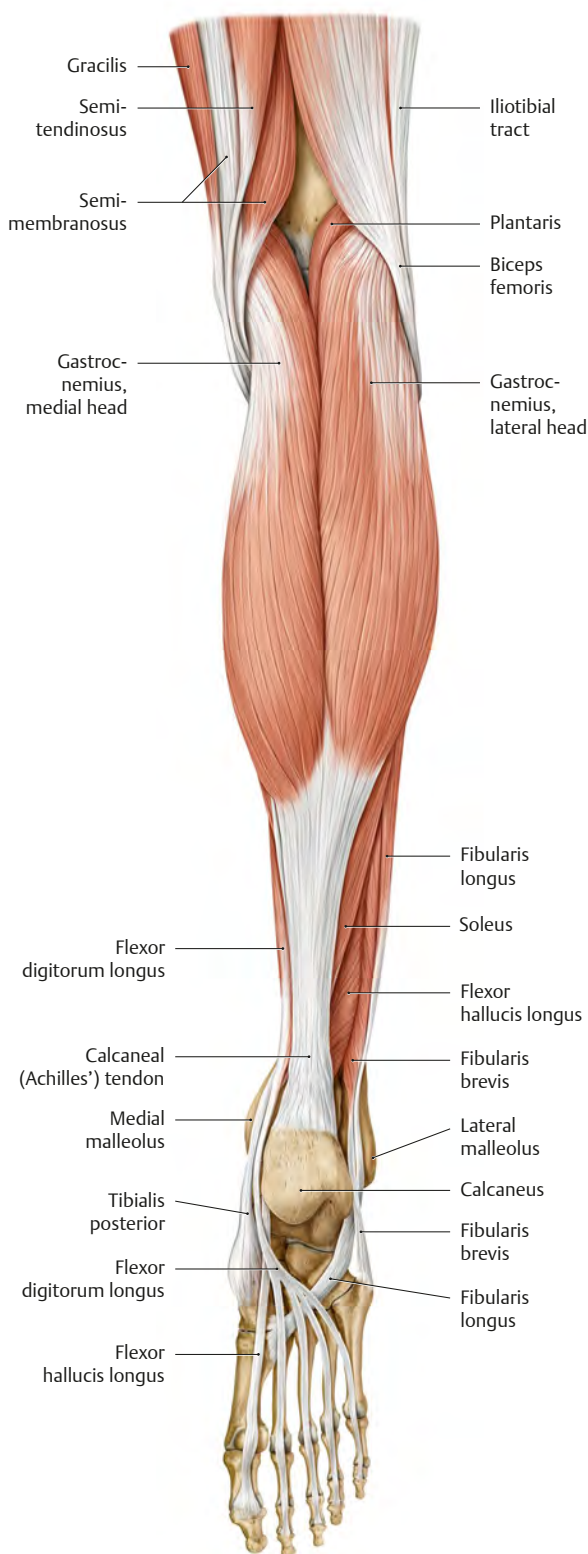


C Removed: All muscles.

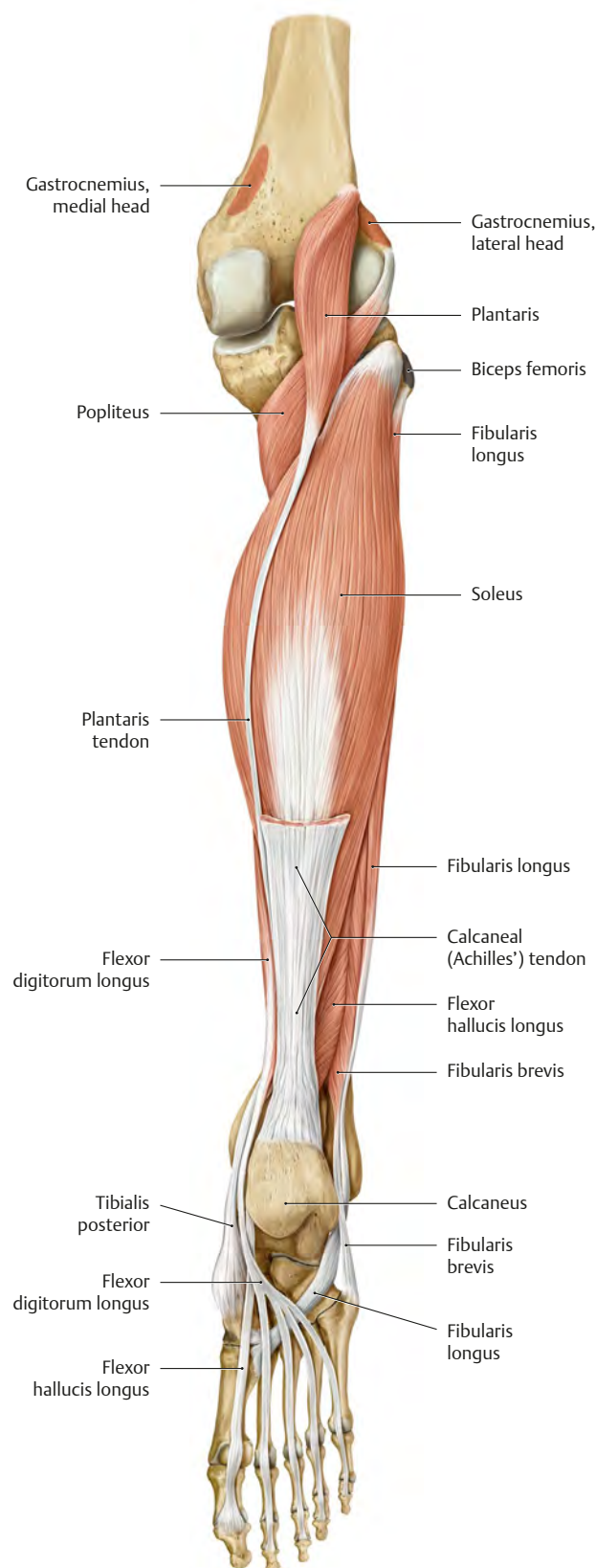


Muscles of the Leg: Posterior Compartment

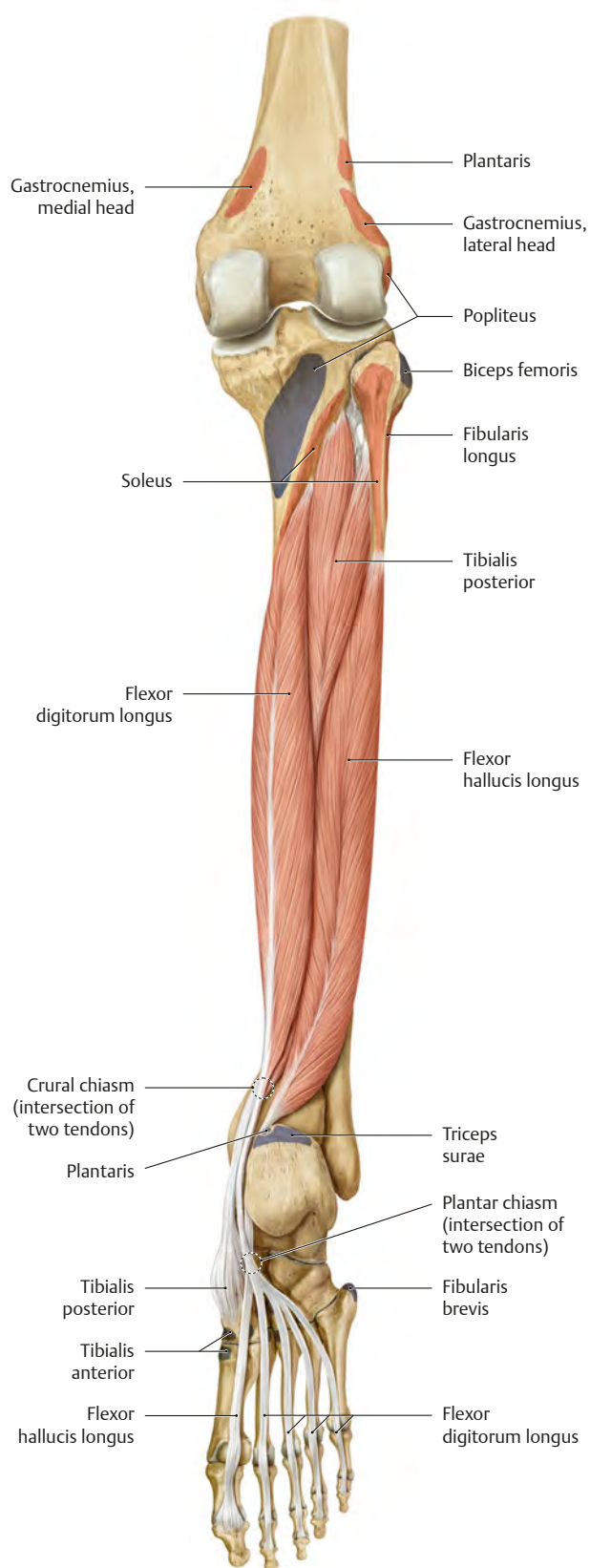
Fig. 32.20 Muscles of the posterior compartment of the leg
Right leg. Muscle origins shown in red, insertions in blue.



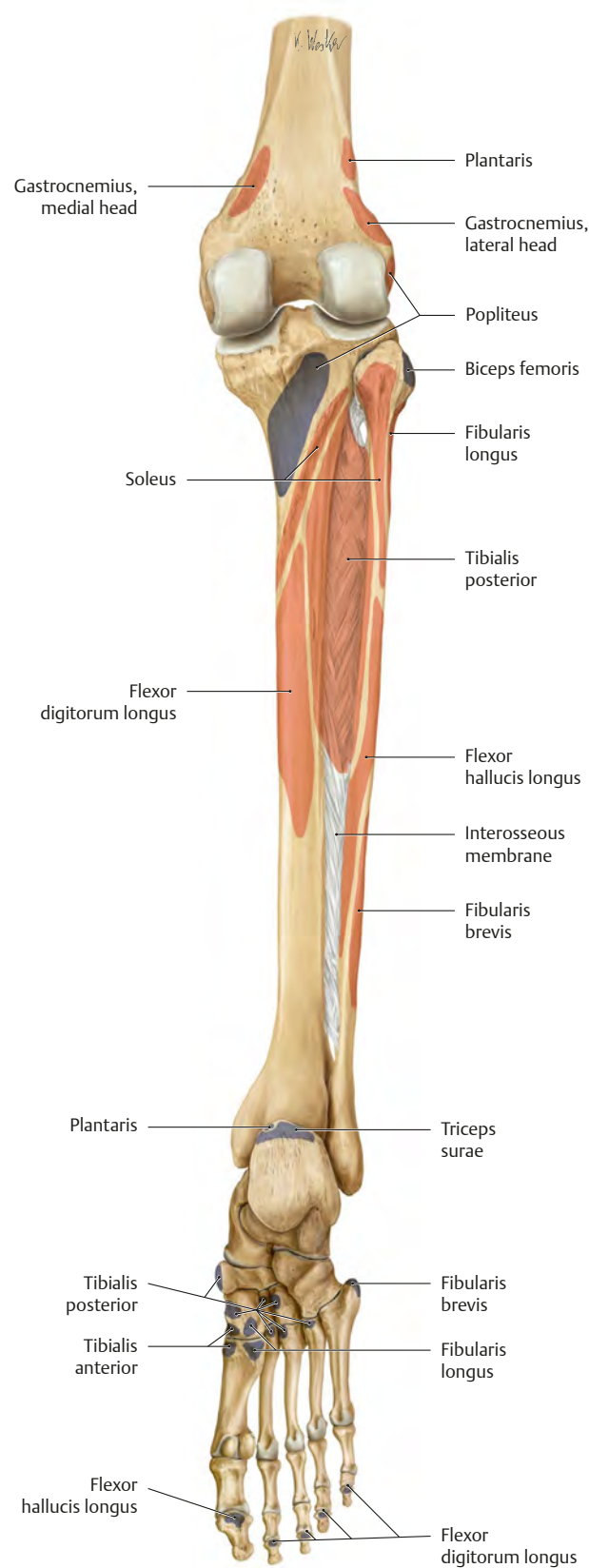
A Note: The bulge of the calf is produced mainly by the triceps surae (soleus and the two heads of the gastrocnemius).



B Removed: Gastrocnemius (both heads).



C Removed: Triceps surae, plantaris, popliteus, fibularis longus, and fibularis brevis muscles.



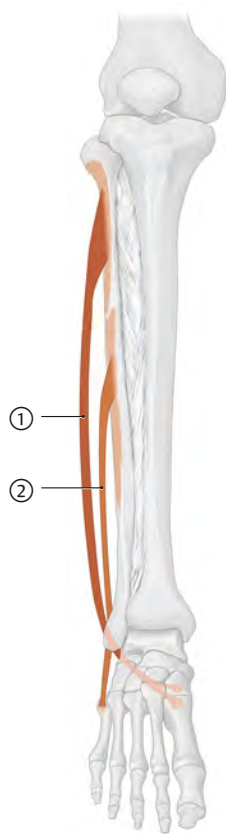
D Removed: All muscles.

Muscle Facts (I)

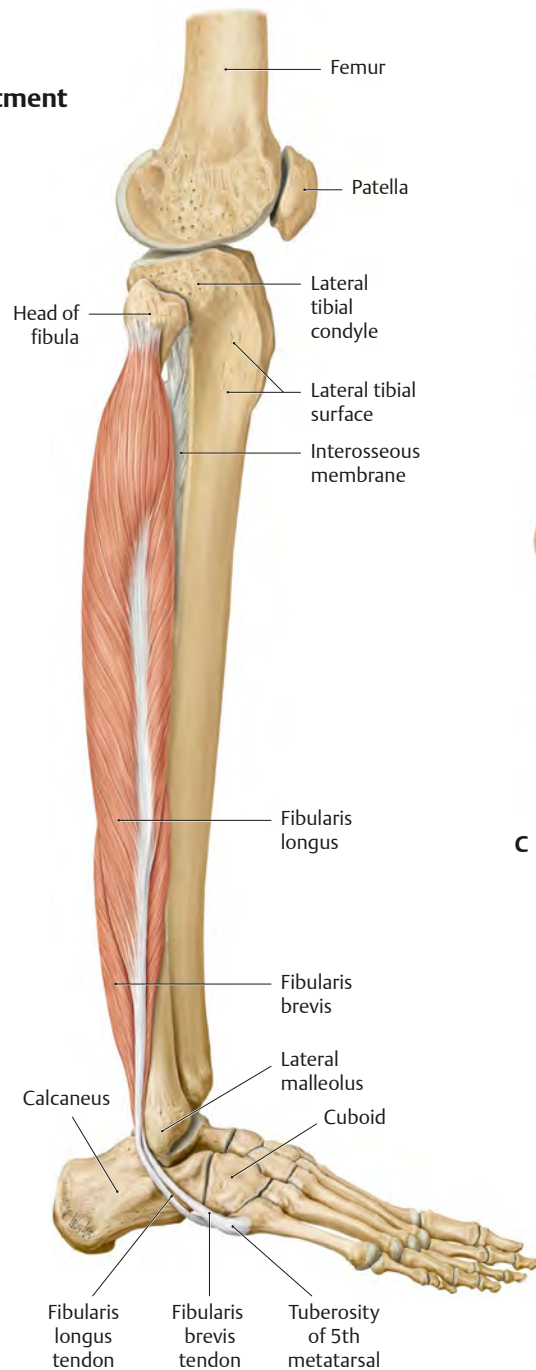
The muscles of the leg control the flexion/extension and inversion/eversion of the foot, which provide stability to the lower limb during movements at the knee and hip joint.

Fig. 32.21 Muscles of the lateral compartment of the leg

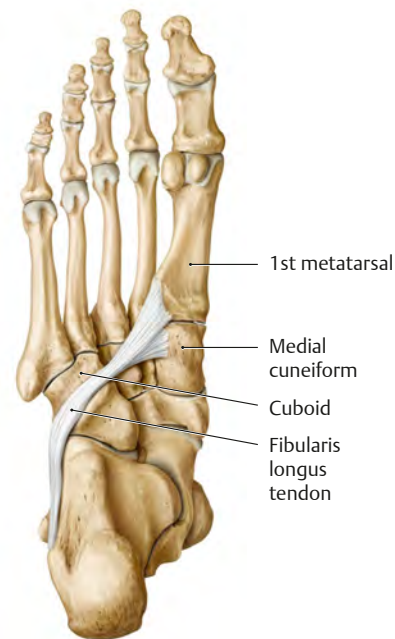
Right leg and foot.



A Fibularis muscles, anterior view, schematic.



B Lateral compartment, right lateral view.



C Course of the fibularis longus tendon, plantar view.

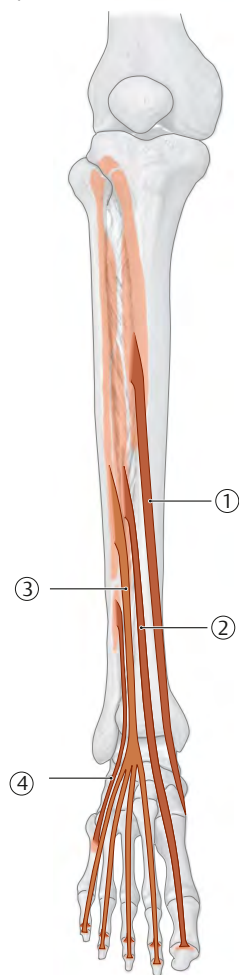
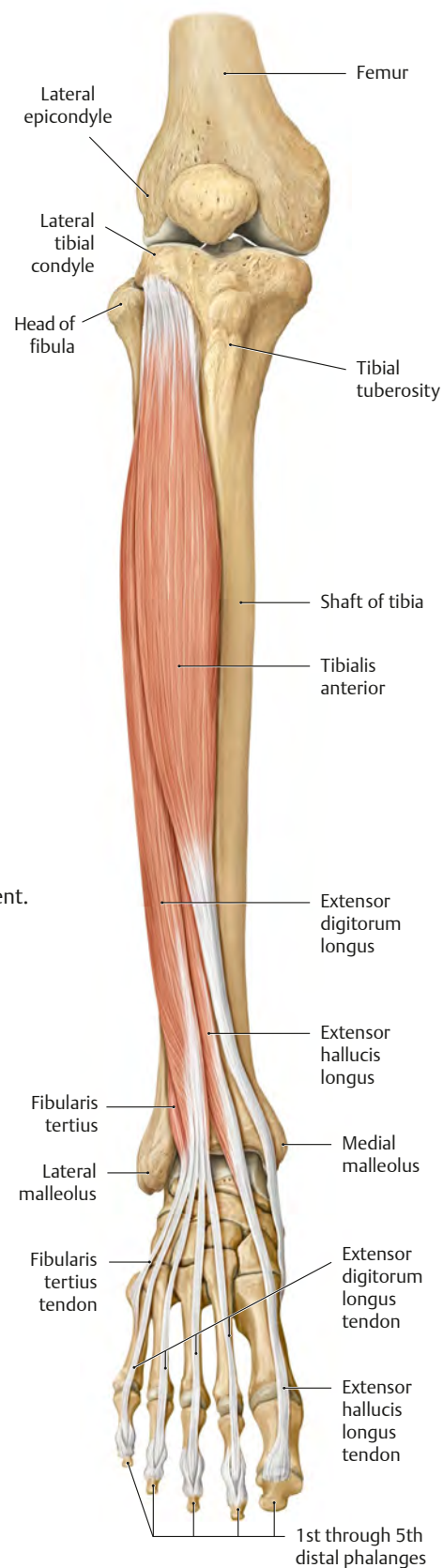
Table 32.2

Lateral compartment

Muscle	Origin	Insertion	Innervation	Action
① Fibularis longus	Fibula (head and proximal two thirds of the lateral surface, arising partly from the intermuscular septa)	Medial cuneiform (plantar side), 1st metatarsal (base)	Superficial fibular n. (L5, S1)	- Talocrural joint: plantar flexion - Subtalar joint: eversion (pronation) - Supports the transverse arch of the foot
② Fibularis brevis	Fibula (distal half of the lateral surface), intermuscular septa	5th metatarsal (tuberosity at the base, with an occasional division to the dorsal aponeurosis of the 5th toe)		- Talocrural joint: plantar flexion - Subtalar joint: eversion (pronation)

Fig. 32.22 Muscles of the anterior compartment of the leg

Right leg, anterior view.

**A** Schematic.**B** Anterior compartment.**Table 32.3** Anterior compartment

Muscle	Origin	Insertion	Innervation	Action
① Tibialis anterior	Tibia (upper two thirds of the lateral surface), interosseous membrane, and superficial crural fascia (highest part)	Medial cuneiform (medial and plantar surface), first metatarsal (medial base)	Deep fibular n. (L4, L5)	• Talocrural joint: dorsiflexion • Subtalar joint: inversion (supination)
② Extensor hallucis longus	Fibula (middle third of the medial surface), interosseous membrane	1st toe (at the dorsal aponeurosis at the base of its distal phalanx)	Deep fibular n. (L4, L5)	• Talocrural joint: dorsiflexion • Subtalar joint: active in both eversion and inversion (pronation/supination), depending on the initial position of the foot • Extends the MTP and IP joints of the big toe
③ Extensor digitorum longus	Fibula (head and medial surface), tibia (lateral condyle), and interosseous membrane	2nd to 5th toes (at the dorsal aponeuroses at the bases of the distal phalanges)	Deep fibular n. (L4, L5)	• Talocrural joint: dorsiflexion • Subtalar joint: eversion (pronation) • Extends the MTP and IP joints of the 2nd to 5th toes
④ Fibularis tertius	Distal fibula (anterior border)	5th metatarsal (base)	Deep fibular n. (L4, L5)	• Talocrural joint: dorsiflexion • Subtalar joint: eversion (pronation)

IP, interphalangeal; MTP, metatarsophalangeal.

Muscle Facts (II)

The muscles of the posterior compartment are divided into two groups: the superficial and deep flexors. These groups are separated by the transverse intermuscular septum.

Fig. 32.23 Muscles of the posterior compartment of the leg: Superficial flexors
Right leg, posterior view.

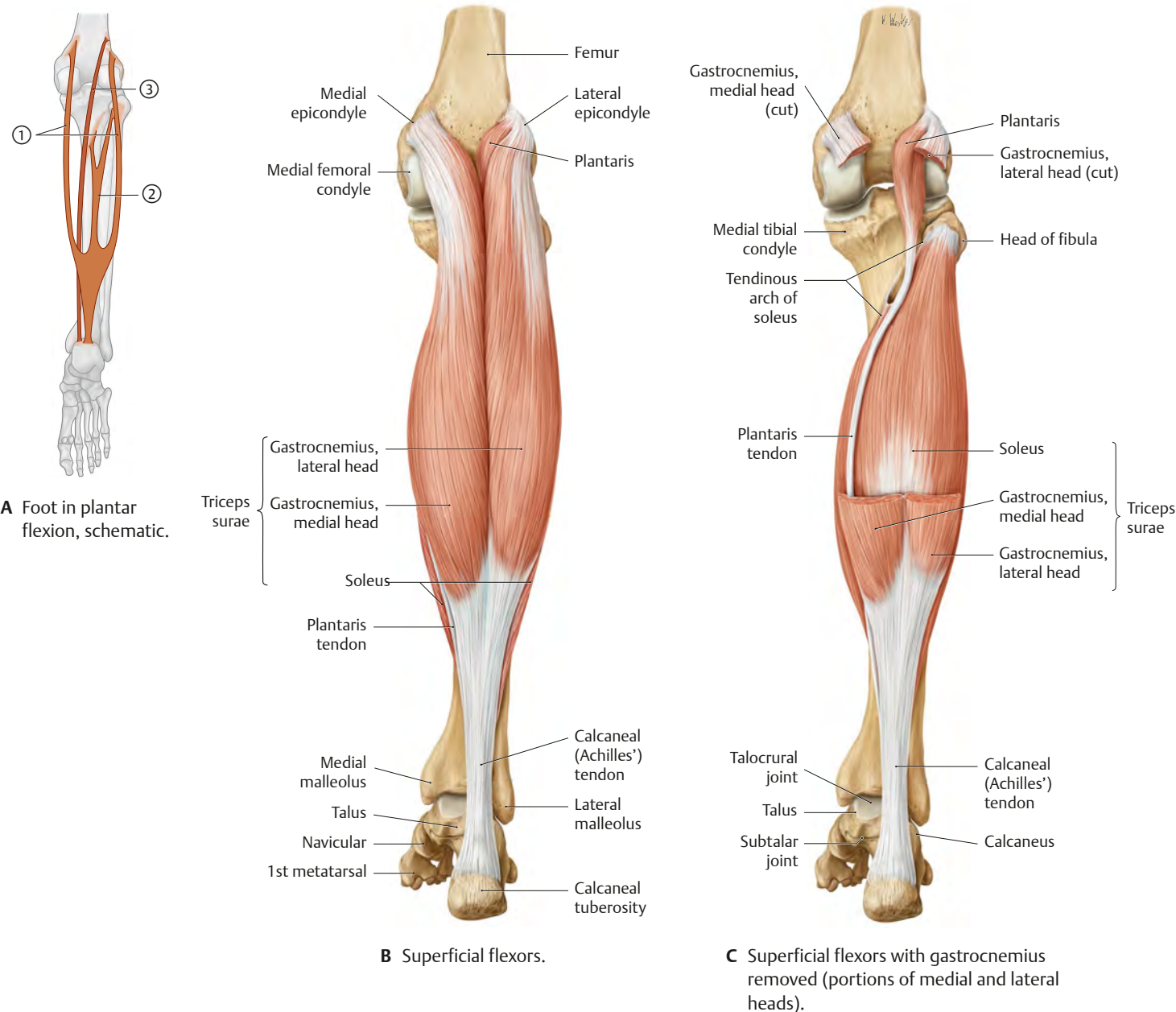


Table 32.4 Superficial flexors of the posterior compartment					
Muscle		Origin	Insertion	Innervation	Action
Triceps surae	① Gastrocnemius	Femur (medial head: superior posterior part of the medial femoral condyle. lateral head: lateral surface of lateral femoral condyle)	Calcaneal tuberosity via the calcaneal (Achilles') tendon	Tibial n. (S1, S2)	• Talocrural joint: plantar flexion when knee is extended (gastrocnemius) • Knee joint: flexion (gastrocnemius) • Talocrural joint: plantar flexion (soleus)
	② Soleus	Fibula (head and neck, posterior surface), tibia (soleal line via a tendinous arch)			
③ Plantaris		Femur (lateral epicondyle, proximal to lateral head of gastrocnemius)	Calcaneal tuberosity		Negligible; may act with gastrocnemius in plantar flexion

Fig. 32.24 Posterior compartment of the leg: Deep flexors

Right leg with foot in plantar flexion, posterior view.

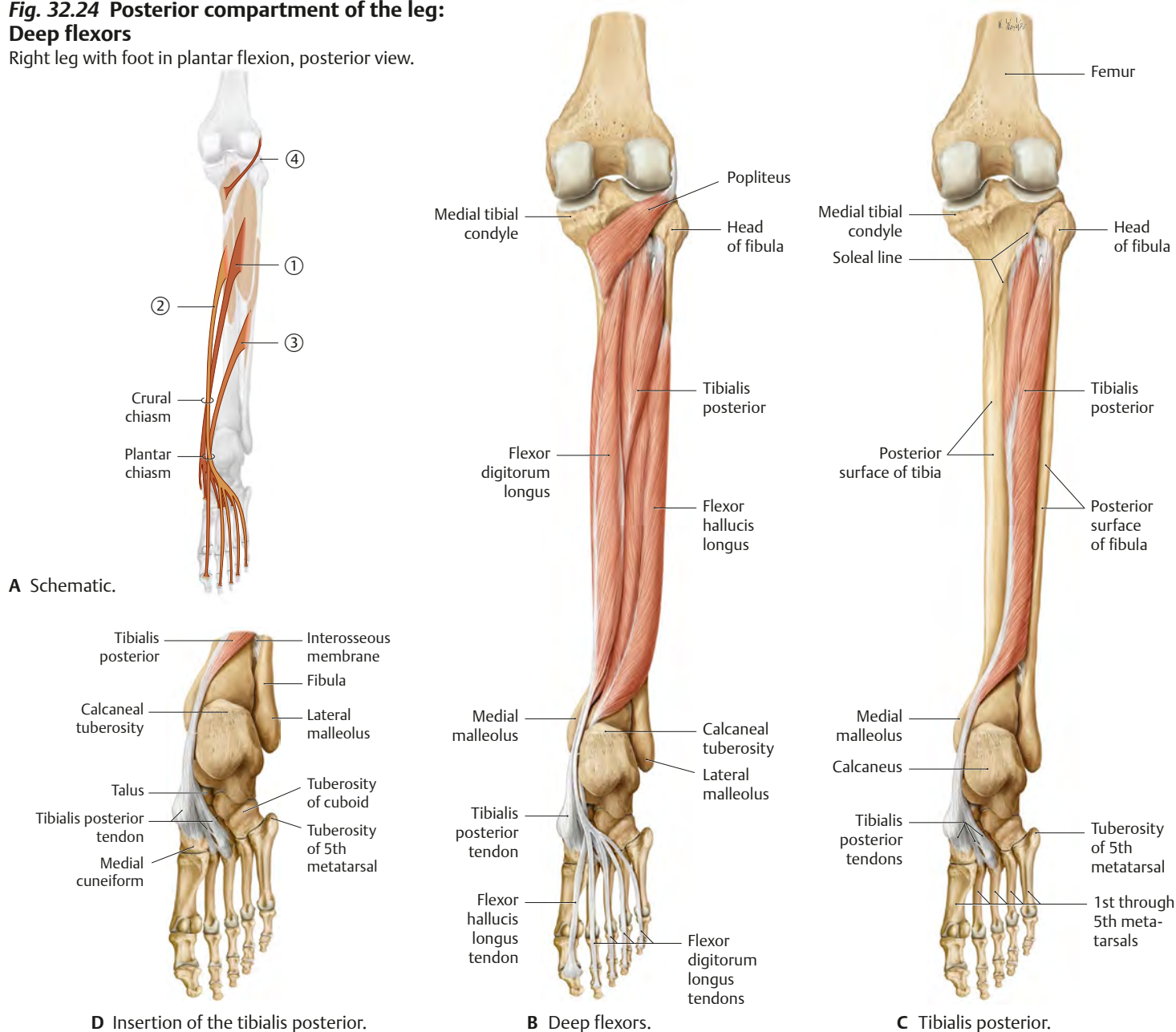


Table 32.5

Deep flexors of the posterior compartment

Muscle	Origin	Insertion	Innervation	Action
① Tibialis posterior	Interosseous membrane, adjacent borders of tibia and fibula	Navicular tuberosity; cuneiforms (medial, intermediate, and lateral); 2nd to 4th metatarsals (bases)	Tibial n. (L4, L5)	• Talocrural joint: plantar flexion • Subtalar joint: inversion (supination) • Supports the longitudinal and transverse arches
② Flexor digitorum longus	Tibia (middle third of posterior surface)	2nd to 5th distal phalanges (bases)	Tibial n. (L5–S2)	• Talocrural joint: plantar flexion • Subtalar joint: inversion (supination) • MTP and IP joints of the 2nd to 5th toes: plantar flexion
③ Flexor hallucis longus	Fibula (distal two thirds of posterior surface), adjacent interosseous membrane	1st distal phalanx (base)		• Talocrural joint: plantar flexion • Subtalar joint: inversion (supination) • MTP and IP joints of the 1st toe: plantar flexion • Supports the medial longitudinal arch
④ Popliteus	Lateral femoral condyle, posterior horn of the lateral meniscus	Posterior tibial surface (above the origin at the soleus)	Tibial n. (L4–S1)	Knee joint: flexes and unlocks the knee by externally rotating the femur on the fixed tibia

IP, interphalangeal; MTP, metatarsophalangeal.

33 Ankle & Foot

Bones of the Foot

Fig. 33.1 Subdivisions of the pedal skeleton

Right foot, dorsal view. Descriptive anatomy divides the skeletal elements of the foot into the tarsus, metatarsus, and forefoot (antetarsus). Functional and clinical criteria divide the pedal skeleton into hindfoot, midfoot, and forefoot.

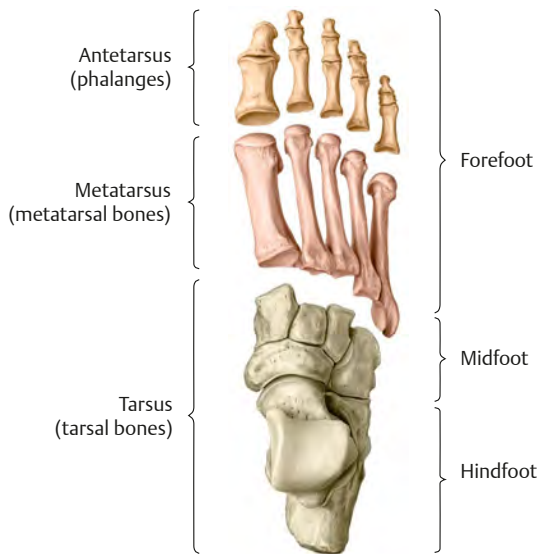
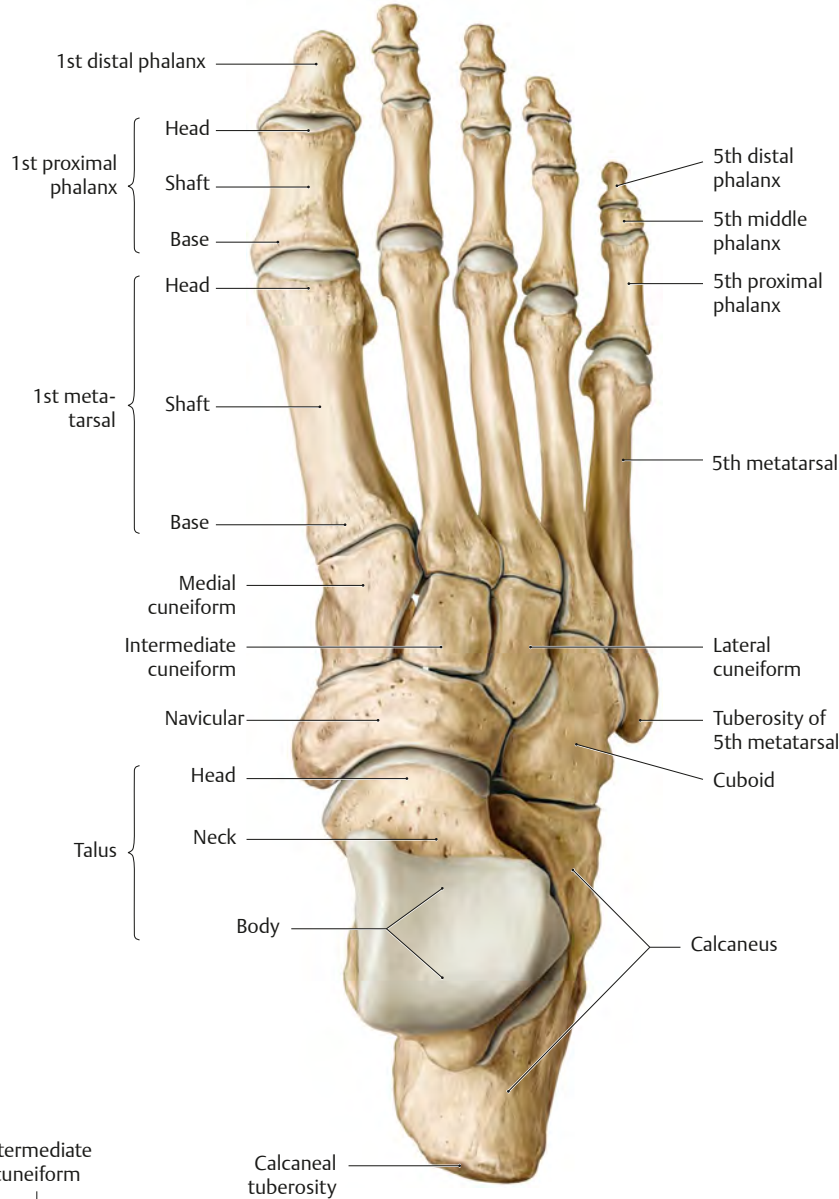
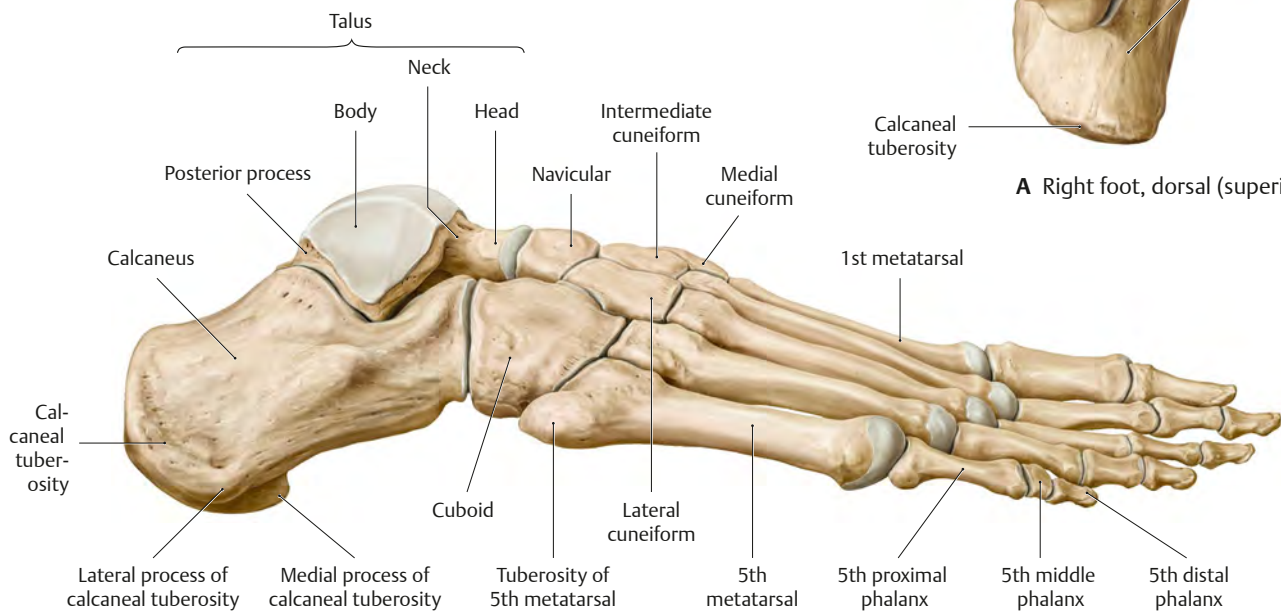


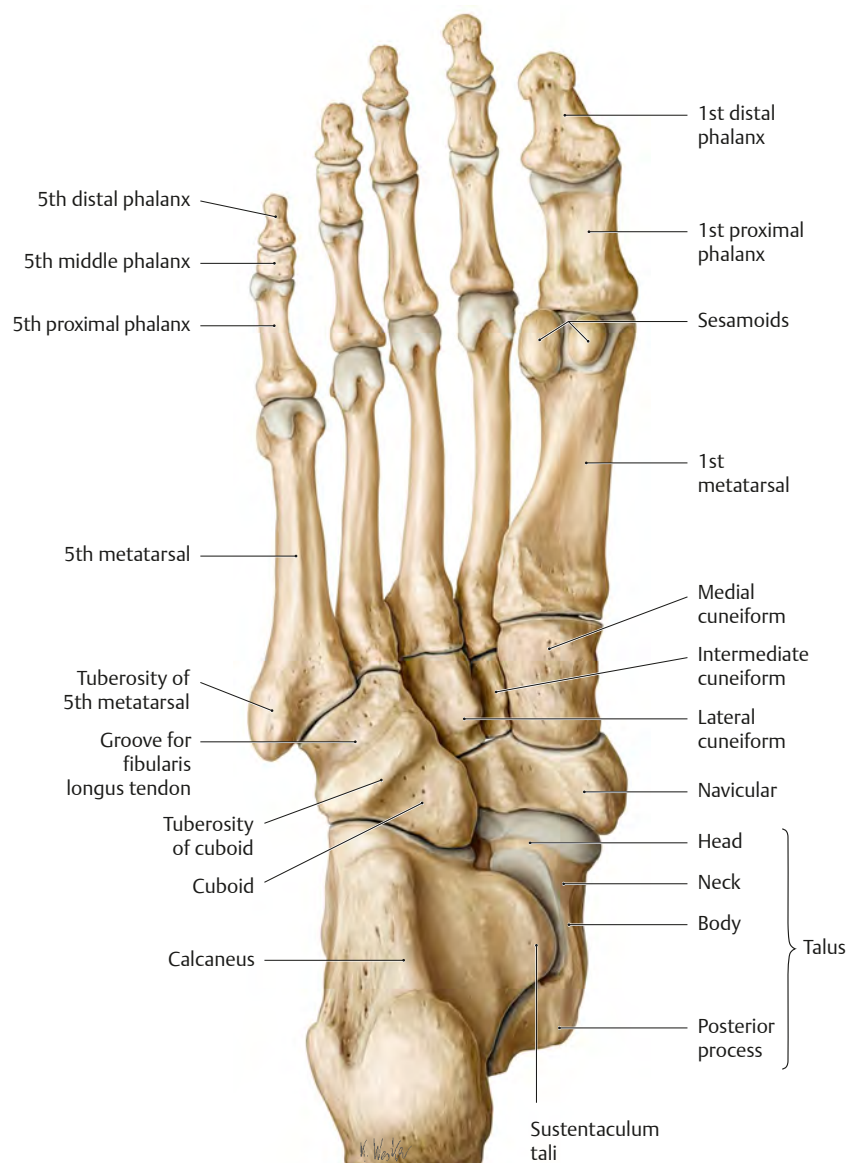
Fig. 33.2 Bones of the foot



A Right foot, dorsal (superior) view.



B Right foot, lateral view.



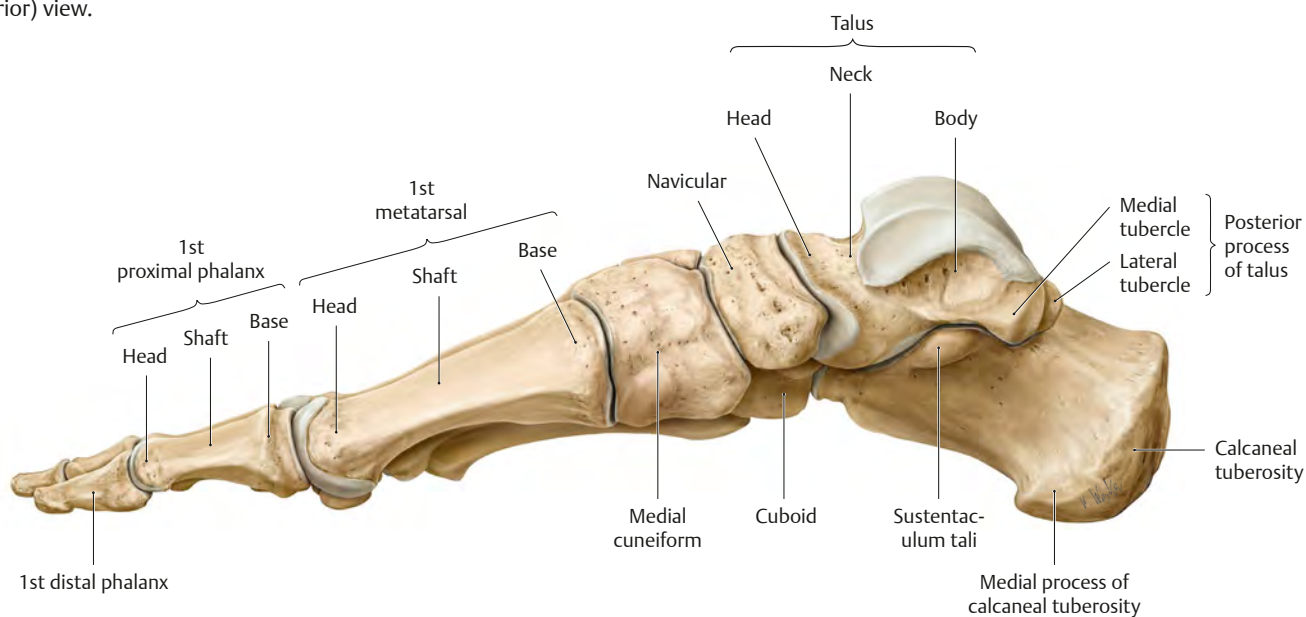
C Right foot, plantar (inferior) view.



Clinical box 33.1

The functional position of the foot

Right foot, lateral view. In the neutral (0°) position, the skeleton of the foot is angled approximately 90° relative to the skeleton of the leg. This *plantigrade* foot position is termed the “functional position” and is an important basis for normal standing and walking.



D Right foot, medial view.

Joints of the Foot (I)

Fig. 33.3 Joints of the foot

Right foot with talocrural joint in plantar flexion.

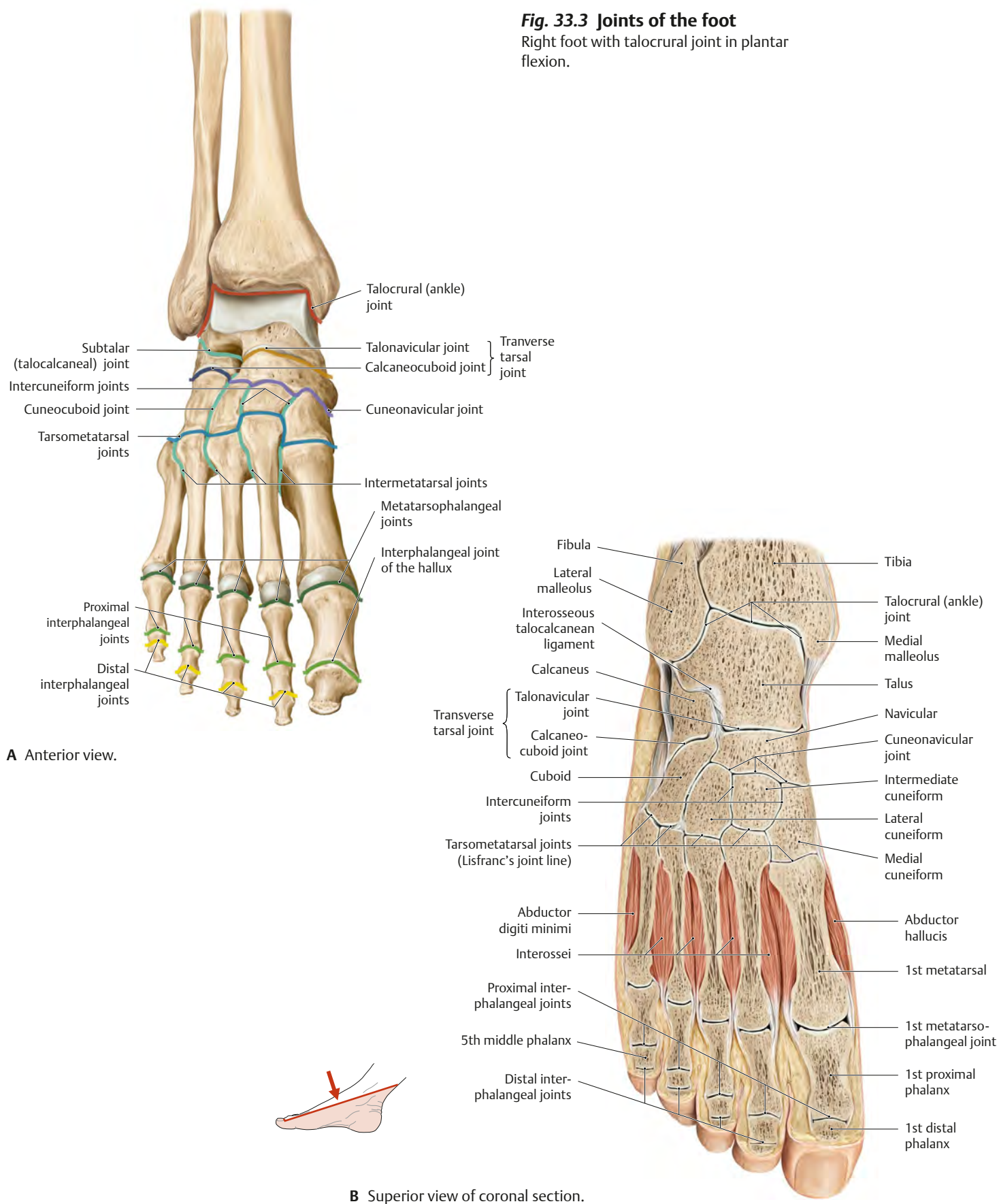
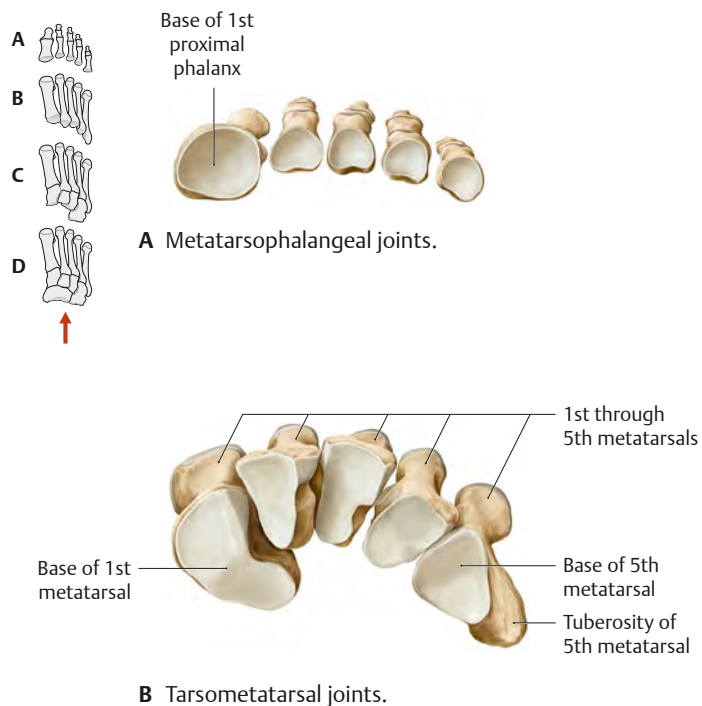
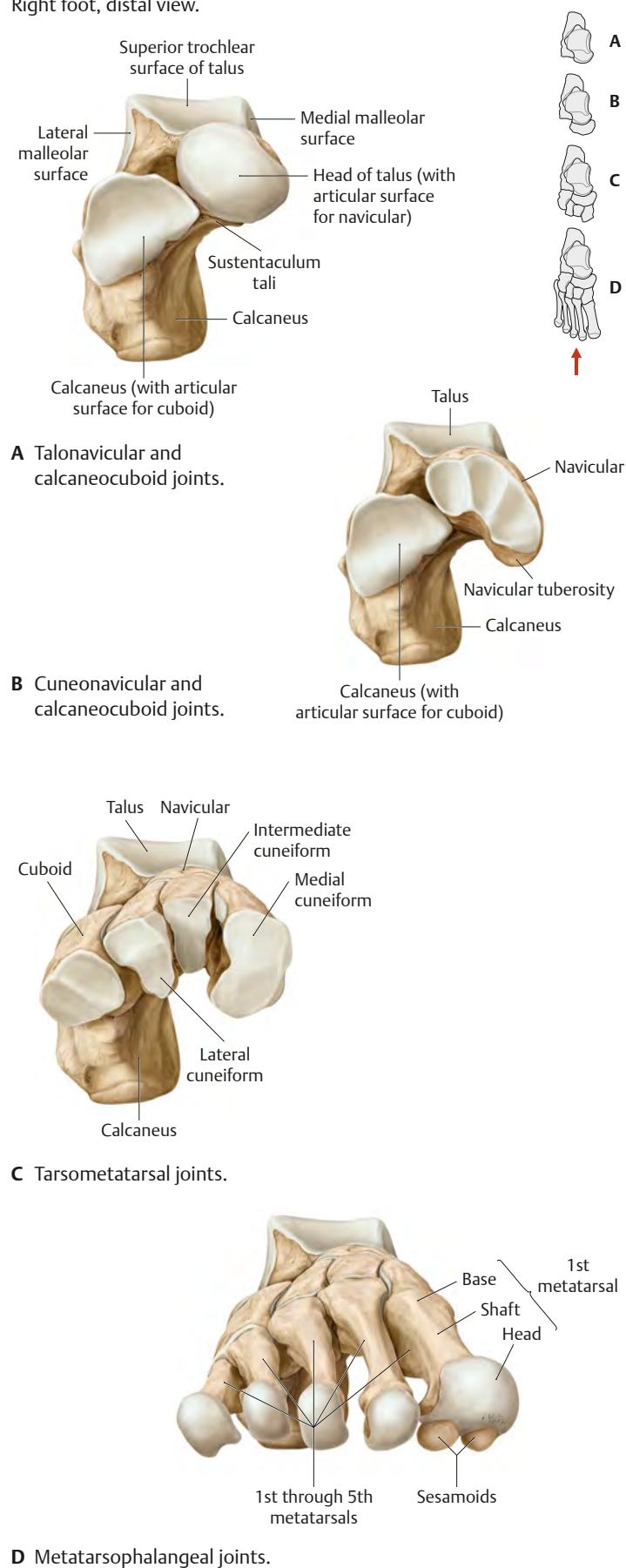


Fig. 33.4 Proximal articular surfaces

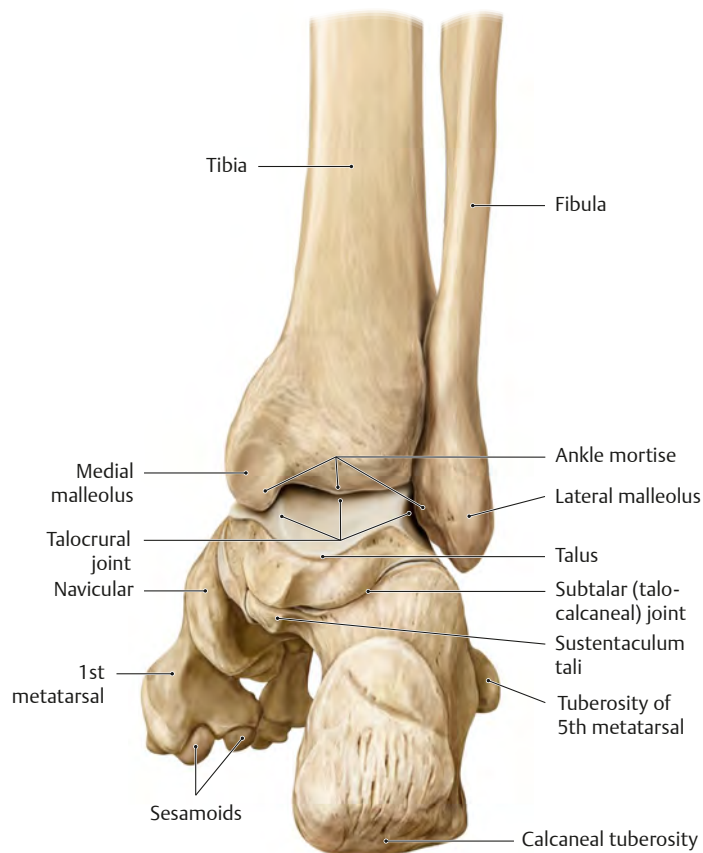
Right foot, proximal view.

**Fig. 33.5 Distal articular surfaces**

Right foot, distal view.



Joints of the Foot (II)



A Posterior view with foot in neutral (0-degree) position.

Fig. 33.6 Talocrural and subtalar joints

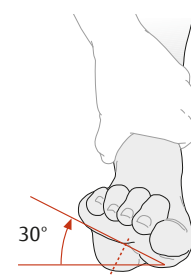
Right foot. The talocrural (ankle) joint is formed by the distal ends of the tibia and fibula (ankle mortise) articulating with the trochlea of the talus. The subtalar joint consists of an anterior and a posterior compartment (the talocalcaneal and talocalcaneonavicular joints, respectively) divided by the interosseous talocalcaneal ligament (see p. 458).



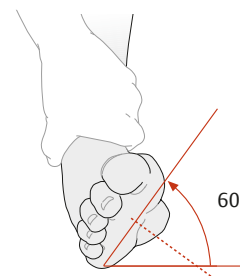
Clinical box 33.2

Range of motion of the forefoot and hindfoot

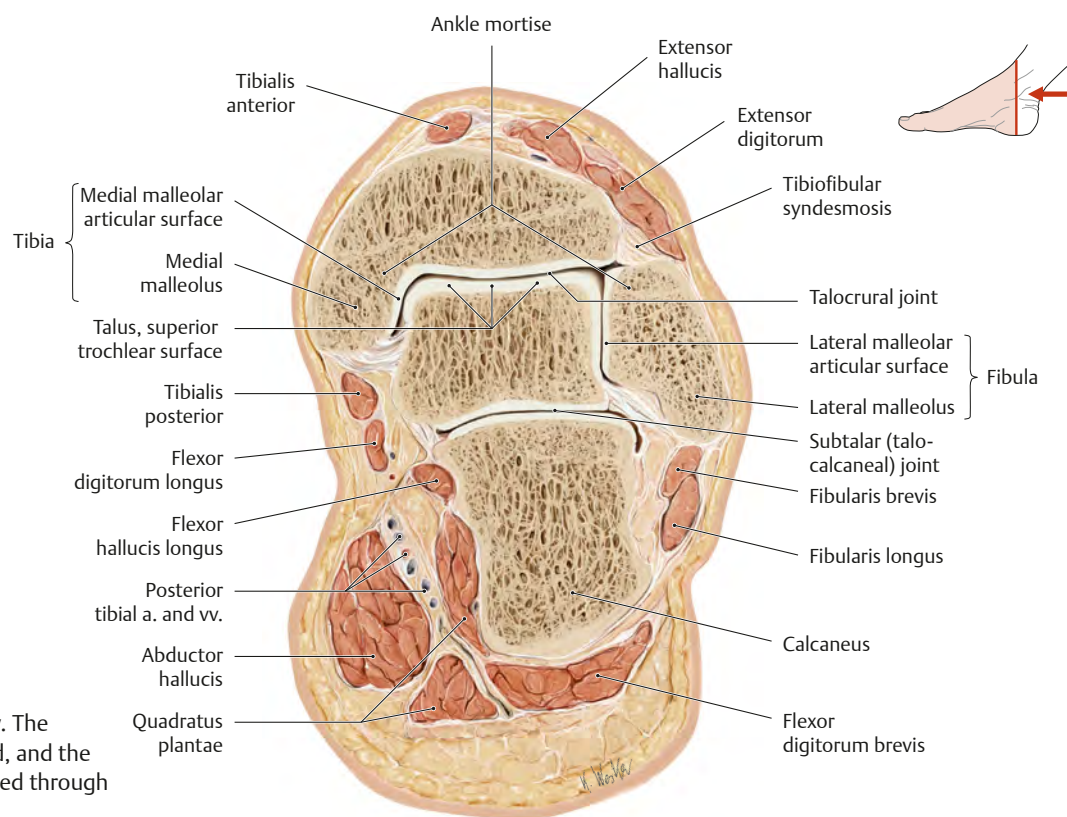
Right foot, anterior view.



A Eversion and pronation of the forefoot.



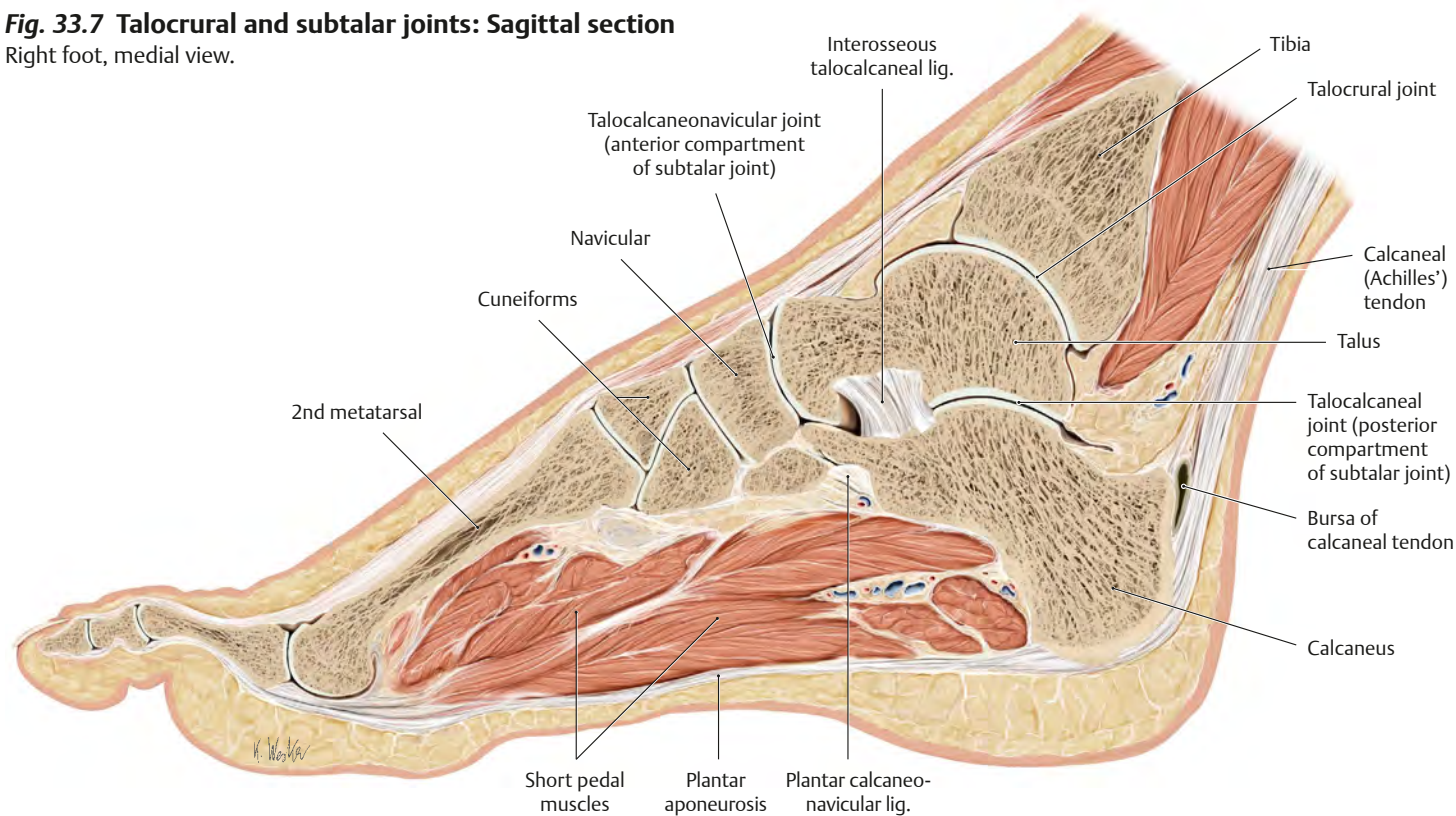
B Inversion and supination of the forefoot.



B Coronal section, proximal view. The talocrural joint is plantar flexed, and the subtalar joint has been sectioned through its posterior compartment.

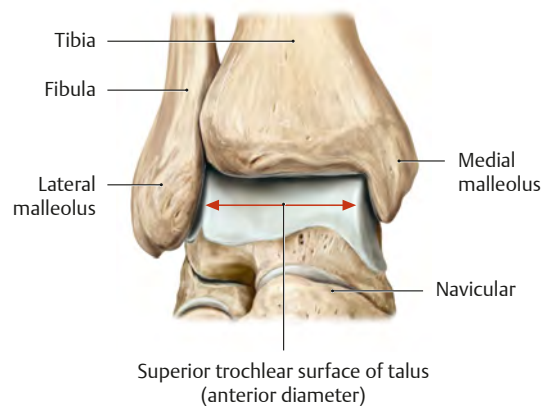
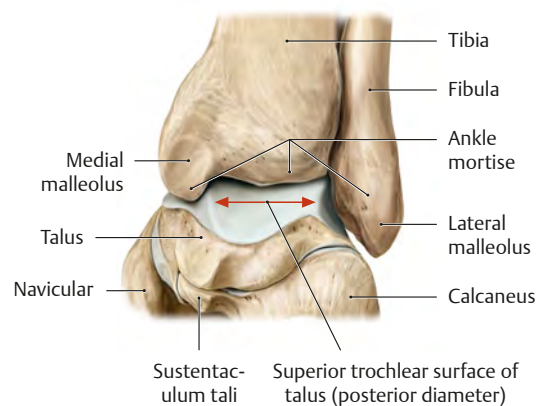
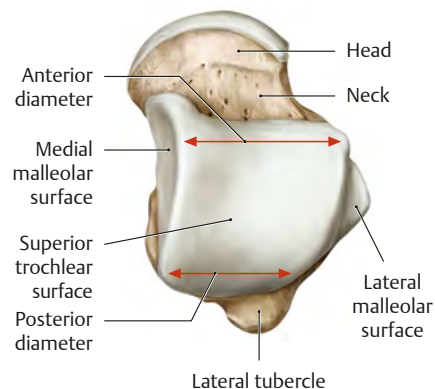
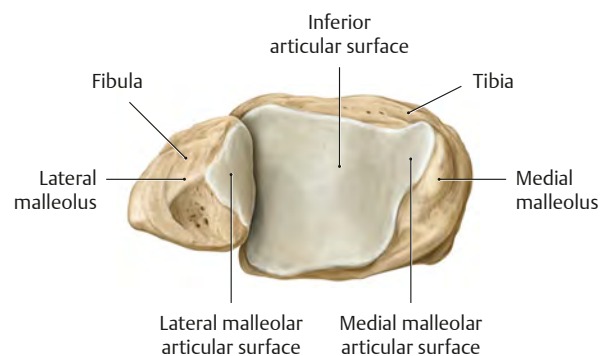
Fig. 33.7 Talocrural and subtalar joints: Sagittal section

Right foot, medial view.

**Fig. 33.8 Talocrural joint**

Right foot. The talocrural (ankle) joint is tighter and more stable with the foot in dorsiflexion, when the wider, anterior part of the trochlea (of

the talus) is wedged within the ankle mortise. Accordingly the joint is looser and less stable in plantar flexion.

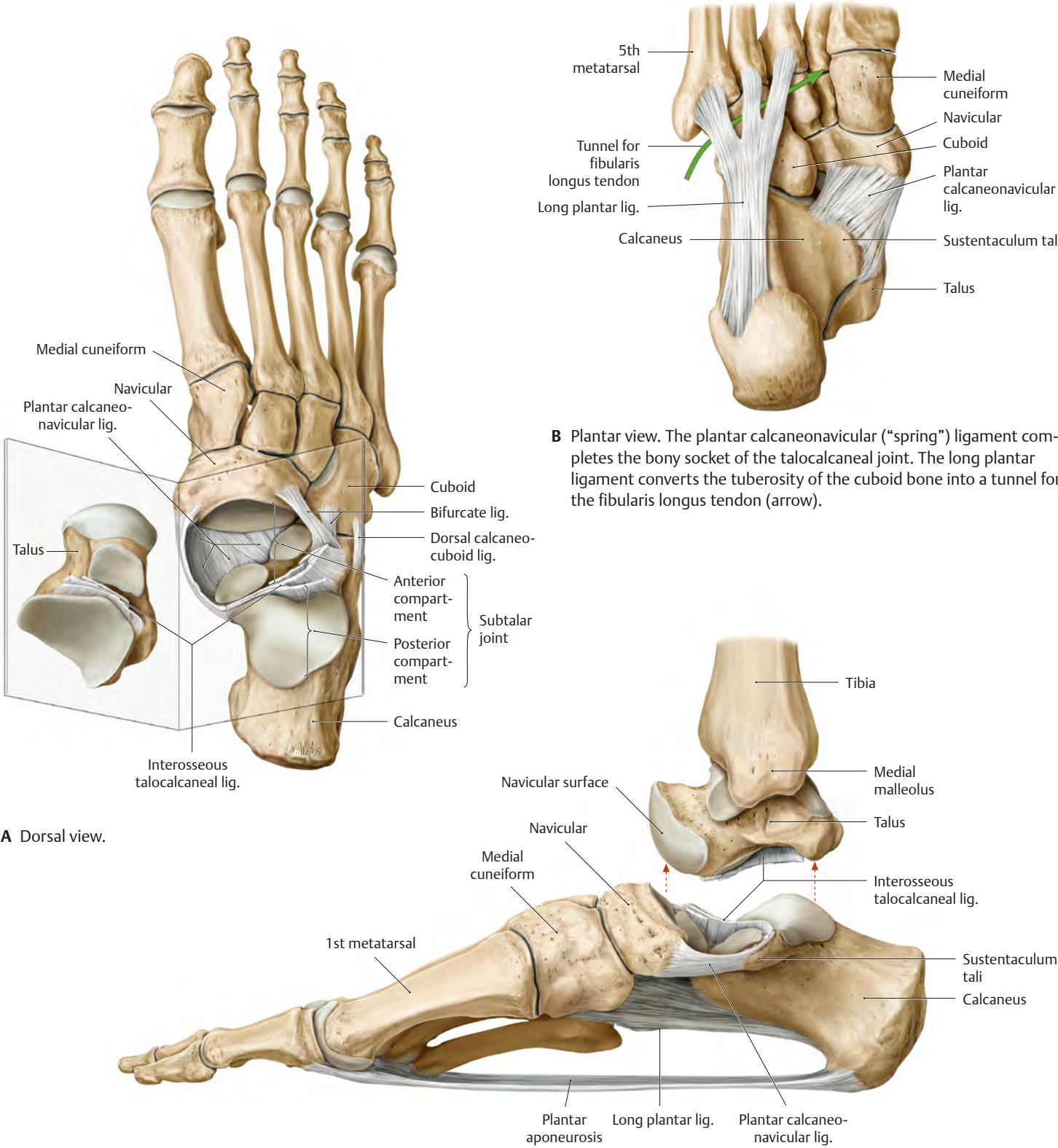
**A Anterior view.****B Posterior view.****C Proximal (superior) view of talus.****D Distal (inferior) view of ankle mortise.**

Joints of the Foot (III)

Fig. 33.9 Subtalar joint and ligaments

Right foot with opened subtalar joint. The subtalar joint consists of two distinct articulations separated by the interosseous talocalcaneal liga-

ment: the posterior compartment (talocalcaneal joint) and the anterior compartment (talocalcaneonavicular joint).



A Dorsal view.

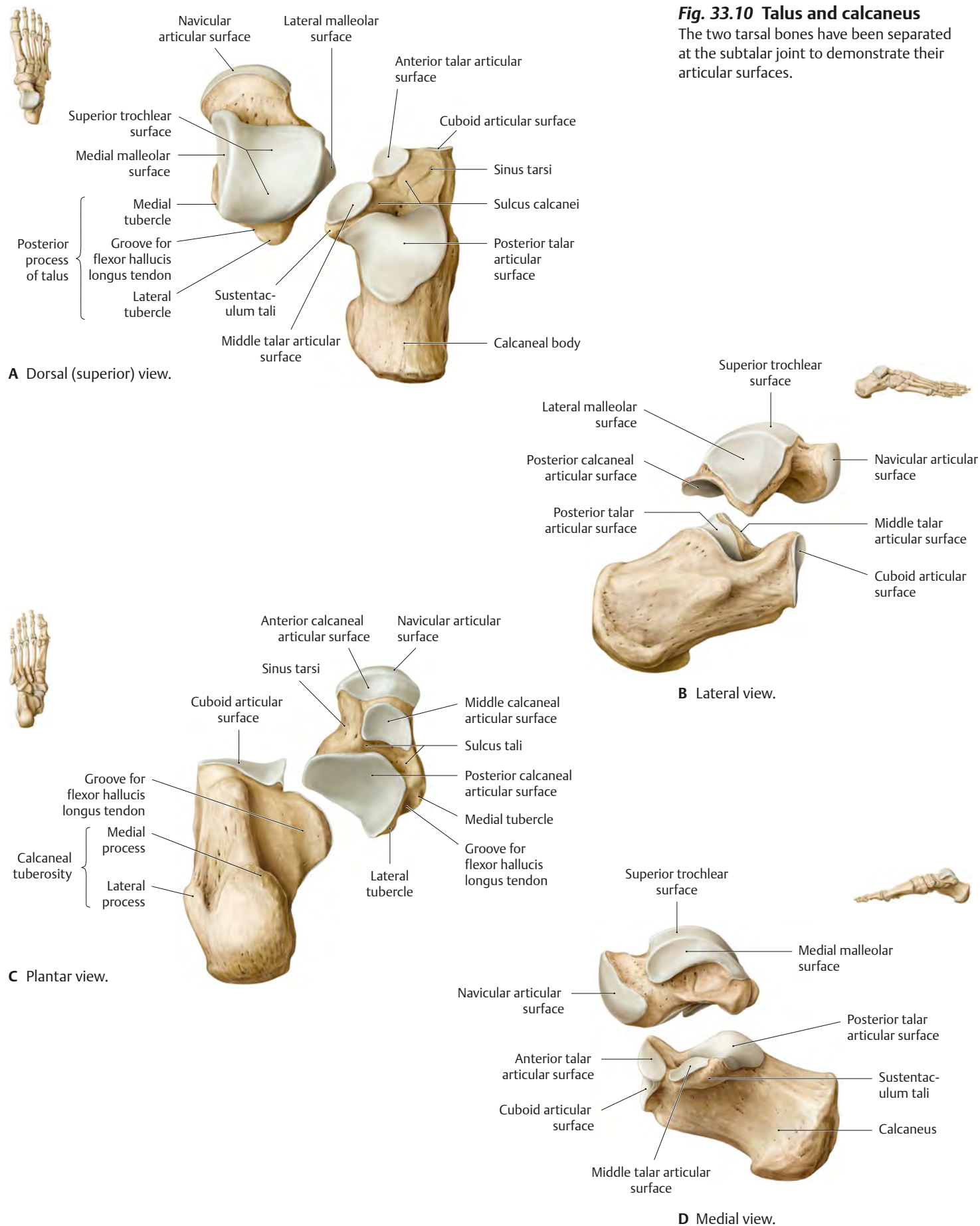
B Plantar view. The plantar calcaneonavicular ("spring") ligament completes the bony socket of the talocalcaneal joint. The long plantar ligament converts the tuberosity of the cuboid bone into a tunnel for the fibularis longus tendon (arrow).

C Medial view. The interosseous talocalcaneal ligament has been divided and the talus displaced upward. Note the course of the plantar calca-

neonavicular ligament, which functions with the long plantar ligament and plantar aponeurosis to support the longitudinal arch of the foot.

Fig. 33.10 Talus and calcaneus

The two tarsal bones have been separated at the subtalar joint to demonstrate their articular surfaces.



Ligaments of the Ankle & Foot

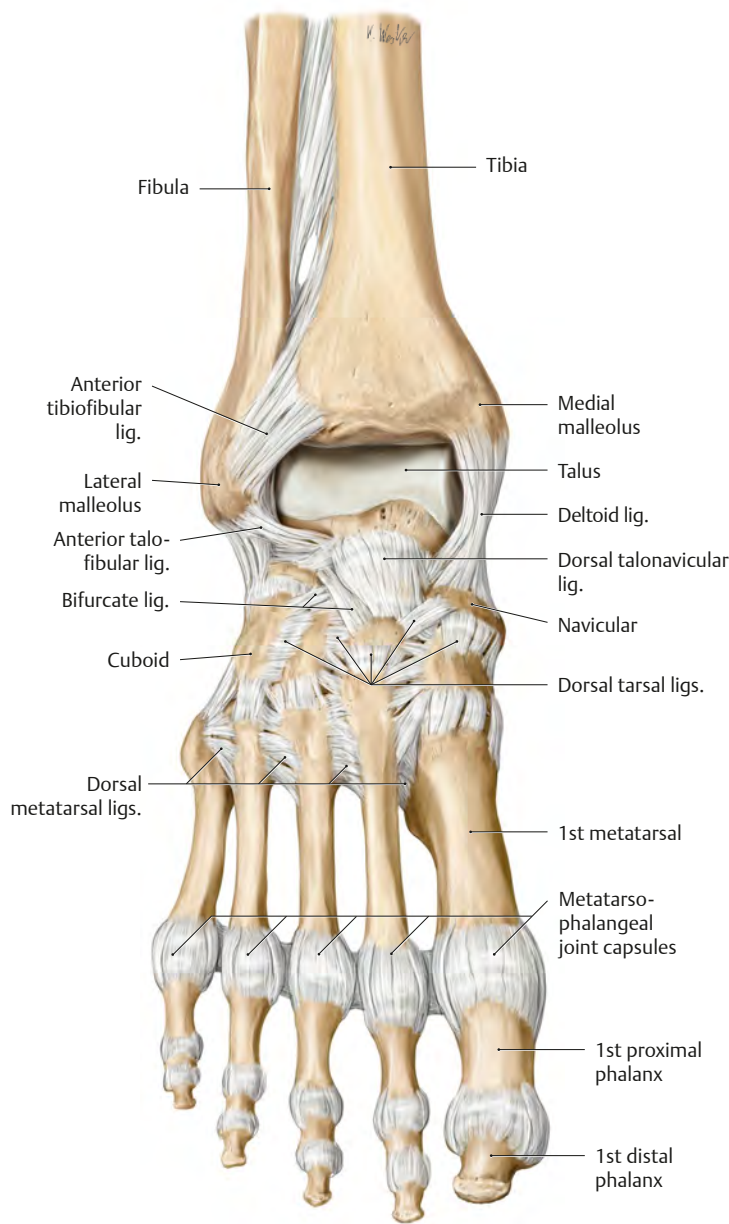
The ligaments of the foot are classified as belonging to the talocrural joint, subtalar joint, metatarsus, forefoot, or sole of the foot. The medial

and lateral collateral ligaments, along with the syndesmotic ligaments, are of major importance in the stabilization of the subtalar joint.

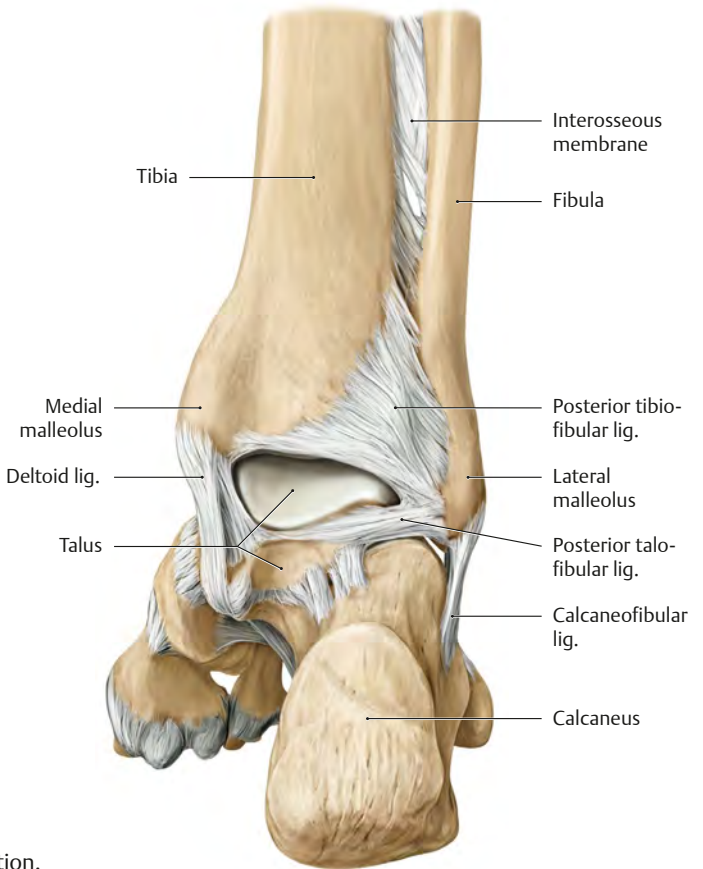
Fig. 33.11 Ligaments of the ankle and foot
Right foot. See p. 458 for inferior view.

Table 33.1 Ligaments of the talocrural joint		
Lateral ligs.*	Anterior talofibular lig.	
	Posterior talofibular lig.	
	Calcaneofibular lig.	
Medial ligs.*	Deltoid lig.	Anterior tibiotalar part
		Posterior tibiotalar part
		Tibionavicular part
		Tibiocalcaneal part
Syndesmotic ligs. of the ankle mortise	Anterior tibiofibular lig.	
	Posterior tibiofibular lig.	

*The medial and lateral ligs. are also known as the medial and lateral collateral ligs.



A Anterior view with talocrural joint in plantar flexion.



B Posterior view in plantigrade foot position.



Plantar Vault & Arches of the Foot

Fig. 33.12 The plantar vault

Right foot. The forces of the foot are distributed among two lateral (fibular) and three medial (tibial) rays. The arrangement of these rays

creates a longitudinal and a transverse arch in the sole of the foot, helping the foot adapt to uneven terrain and absorb vertical loads.

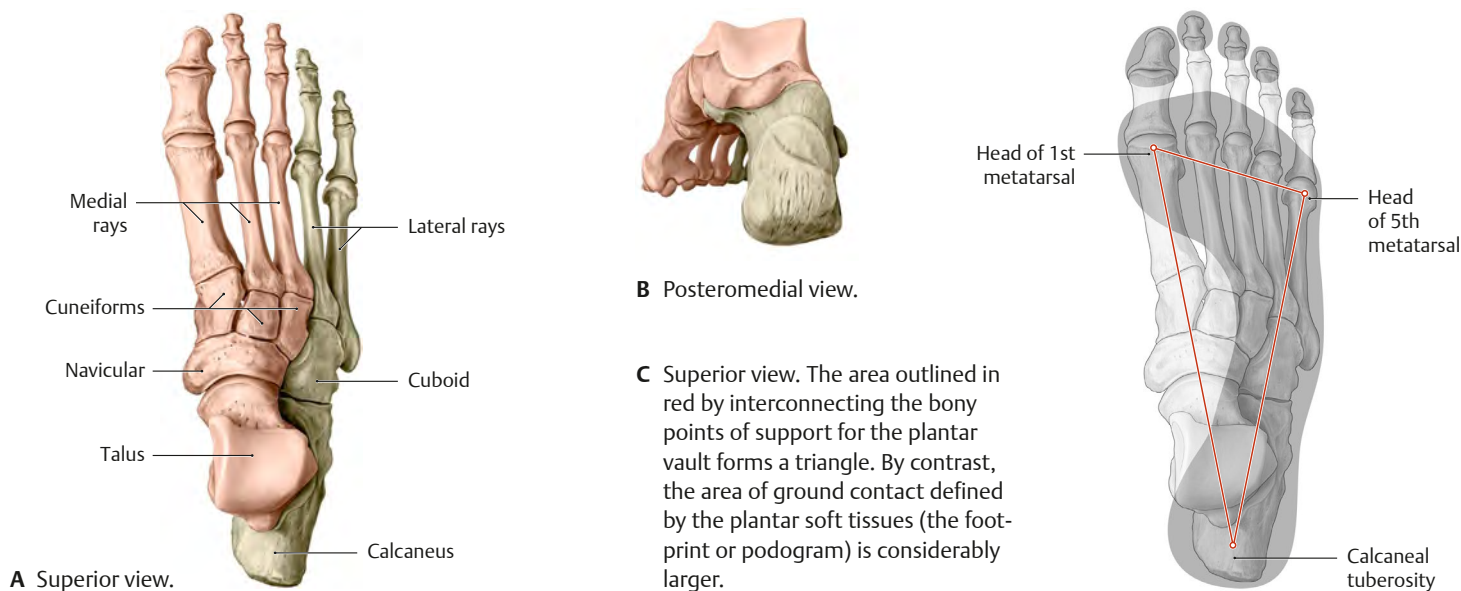


Fig. 33.13 Stabilizers of the transverse arch

Right foot. The transverse pedal arch is supported by both active and passive stabilizing structures (muscles and ligaments, respectively).

Note: The arch of the forefoot has only passive stabilizers, whereas the arches of the metatarsus and tarsus have only active stabilizers.

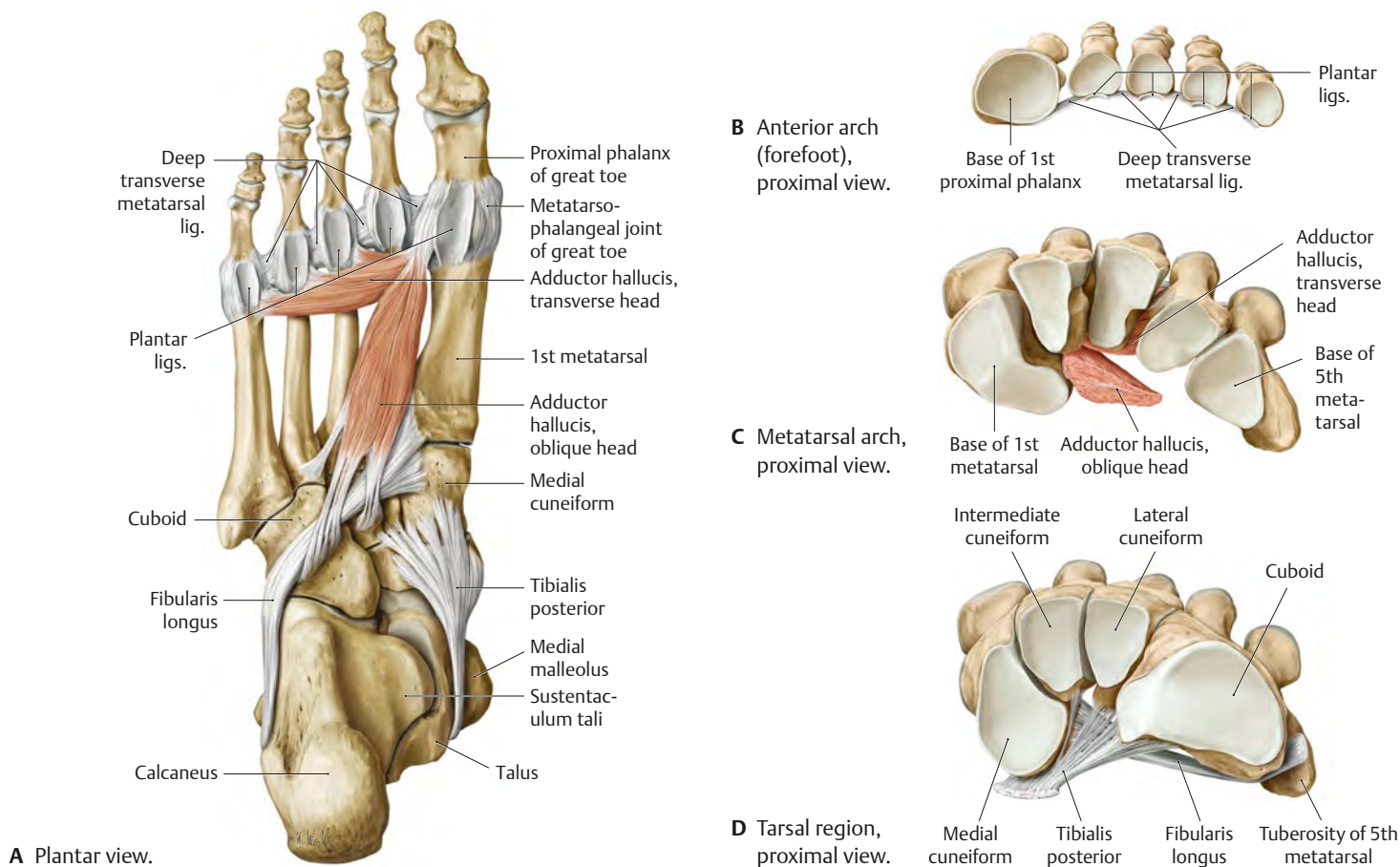
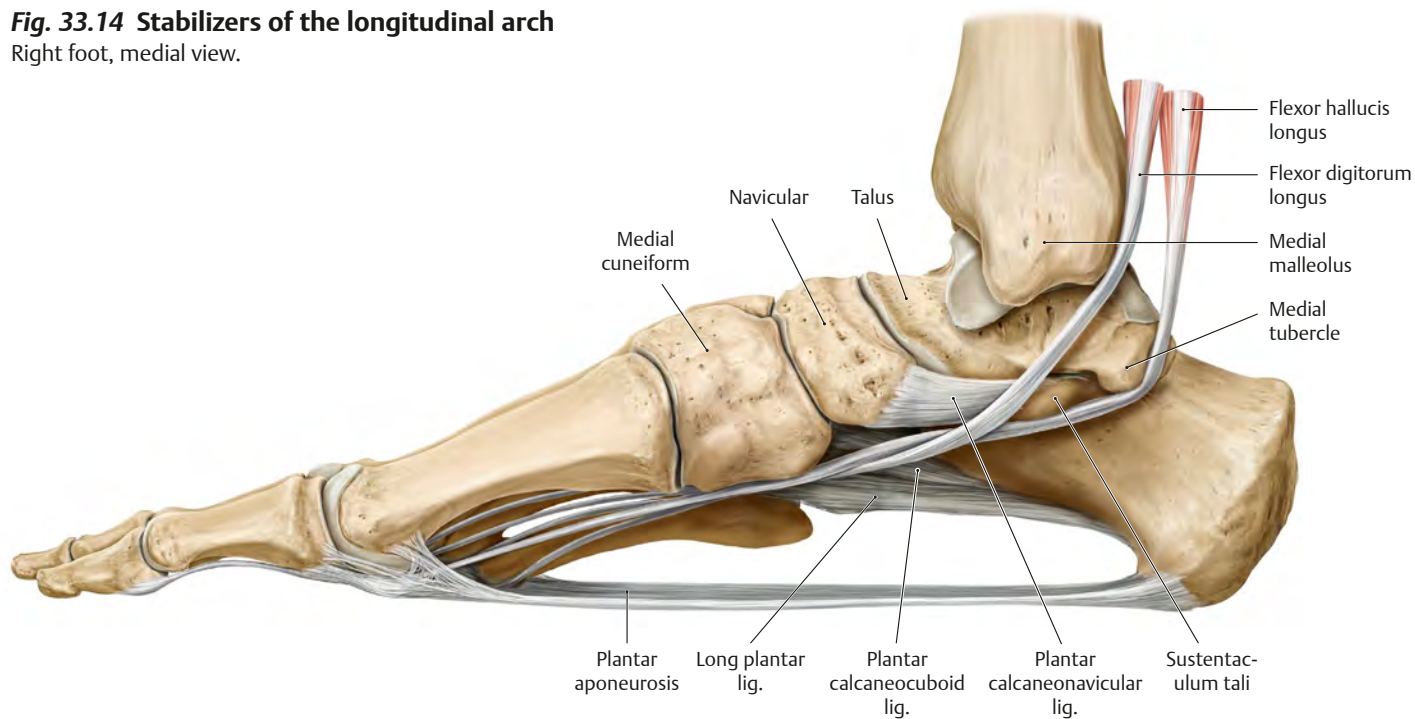
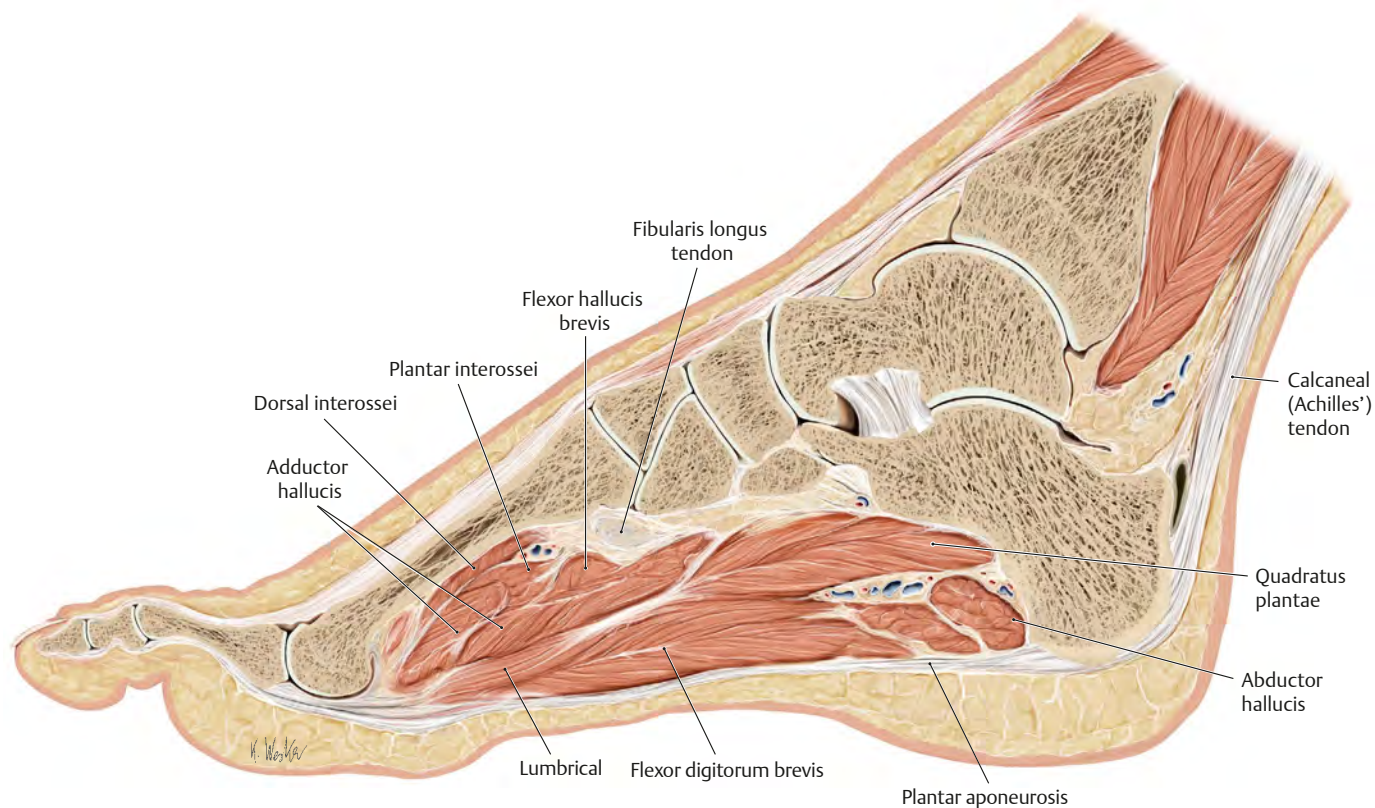


Fig. 33.14 Stabilizers of the longitudinal arch

Right foot, medial view.



A Passive stabilizers of the longitudinal arch. The main passive stabilizers of the longitudinal arch are the plantar aponeurosis (strongest component), the long plantar ligament, and the plantar calcaneonavicular ligament (weakest component).



B Active stabilizers of the longitudinal arch. Sagittal section at the level of the second ray. The major active stabilizers of the foot are the abductor hallucis, flexor hallucis brevis, flexor digitorum brevis, quadratus plantae, and abductor digiti minimi.

Muscles of the Sole of the Foot

Fig. 33.15 Plantar aponeurosis

Right foot, plantar view. The plantar aponeurosis is a tough aponeurotic sheet, thickest at the center, that blends with the dorsal fascia (not shown) at the borders of the foot.

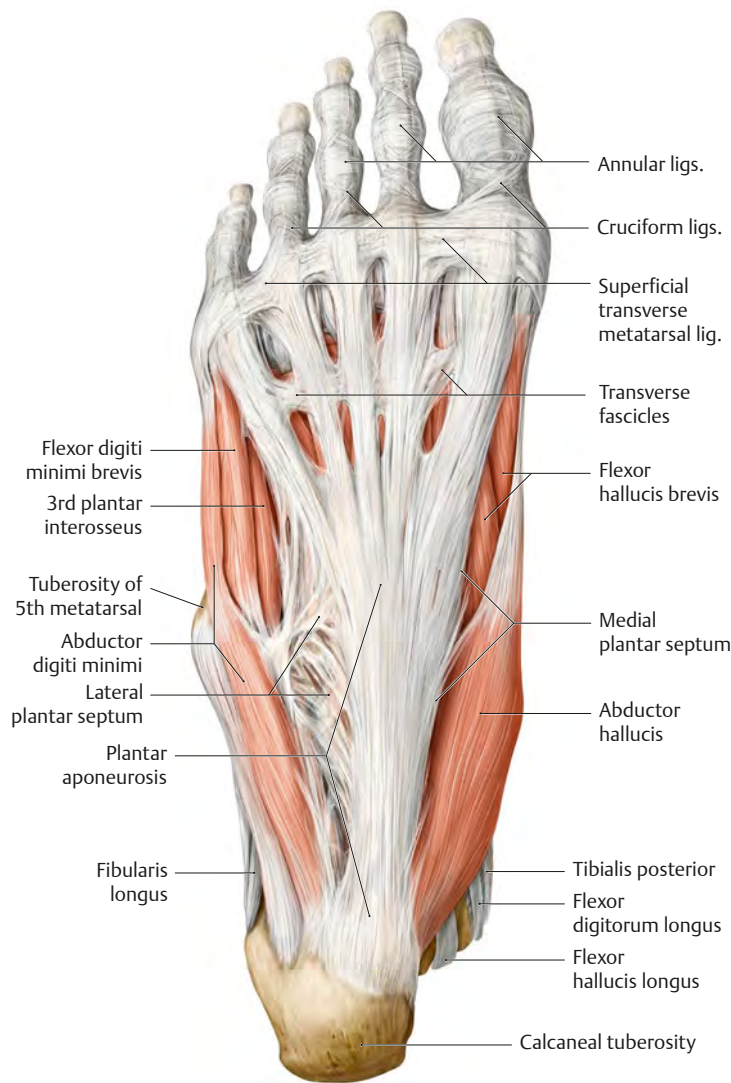
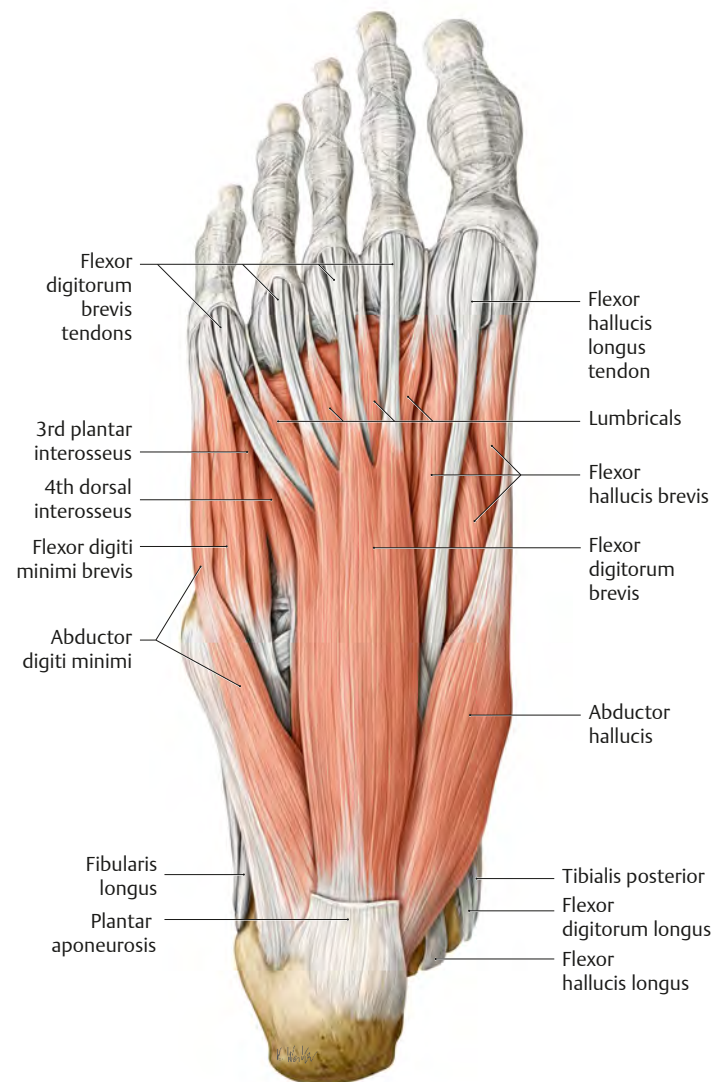
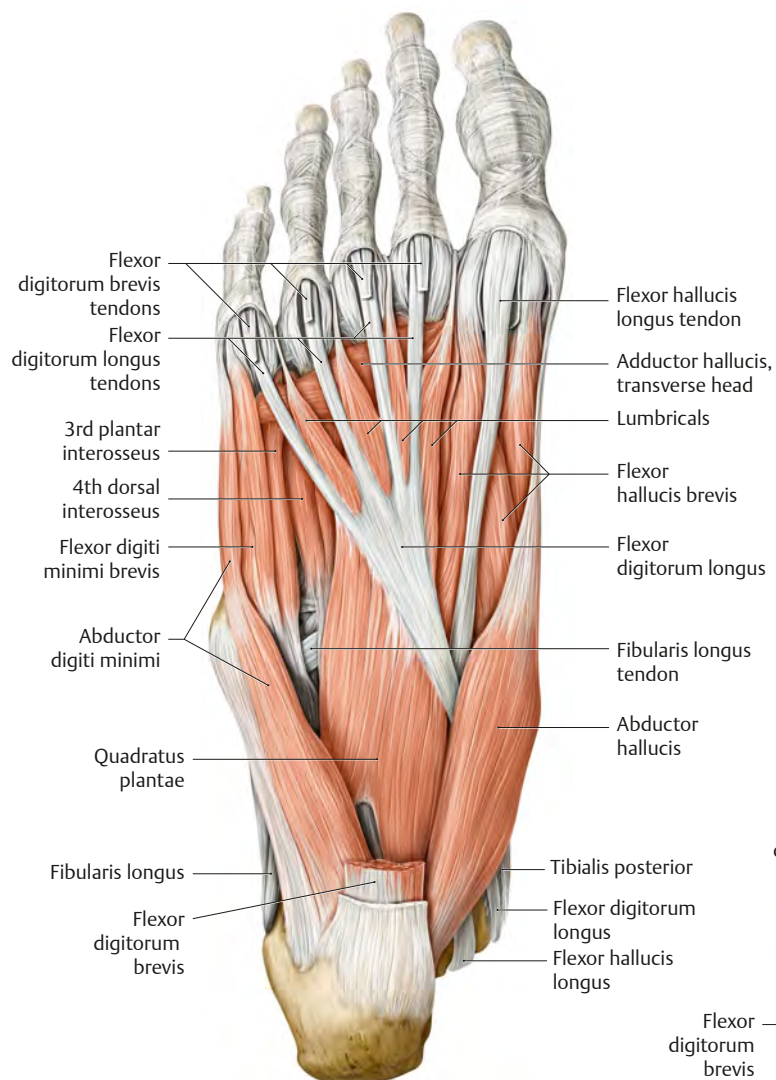


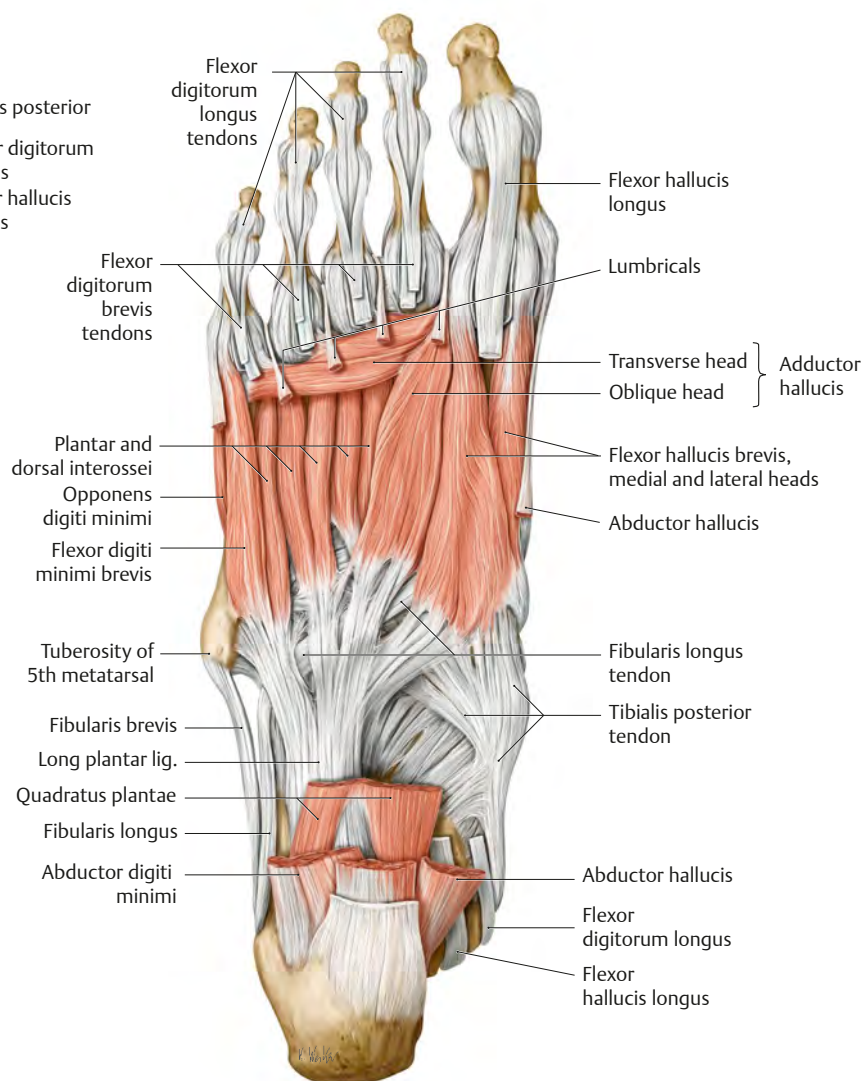
Fig. 33.16 Intrinsic muscles of the sole of the foot
Right foot, plantar view.



A Superficial (first) layer. *Removed:* Plantar aponeurosis, including the superficial transverse metacarpal ligament.



B Second layer. *Removed:* Flexor digitorum brevis.



C Third layer. *Removed:* Abductor digiti minimi, abductor hallucis, quadratus plantae, lumbricals, and tendons of insertion of the flexors digitorum and hallucis longus.

Muscles & Tendon Sheaths of the Foot

Fig. 33.17 Deep intrinsic muscles of the sole of the foot
Right foot, plantar view.

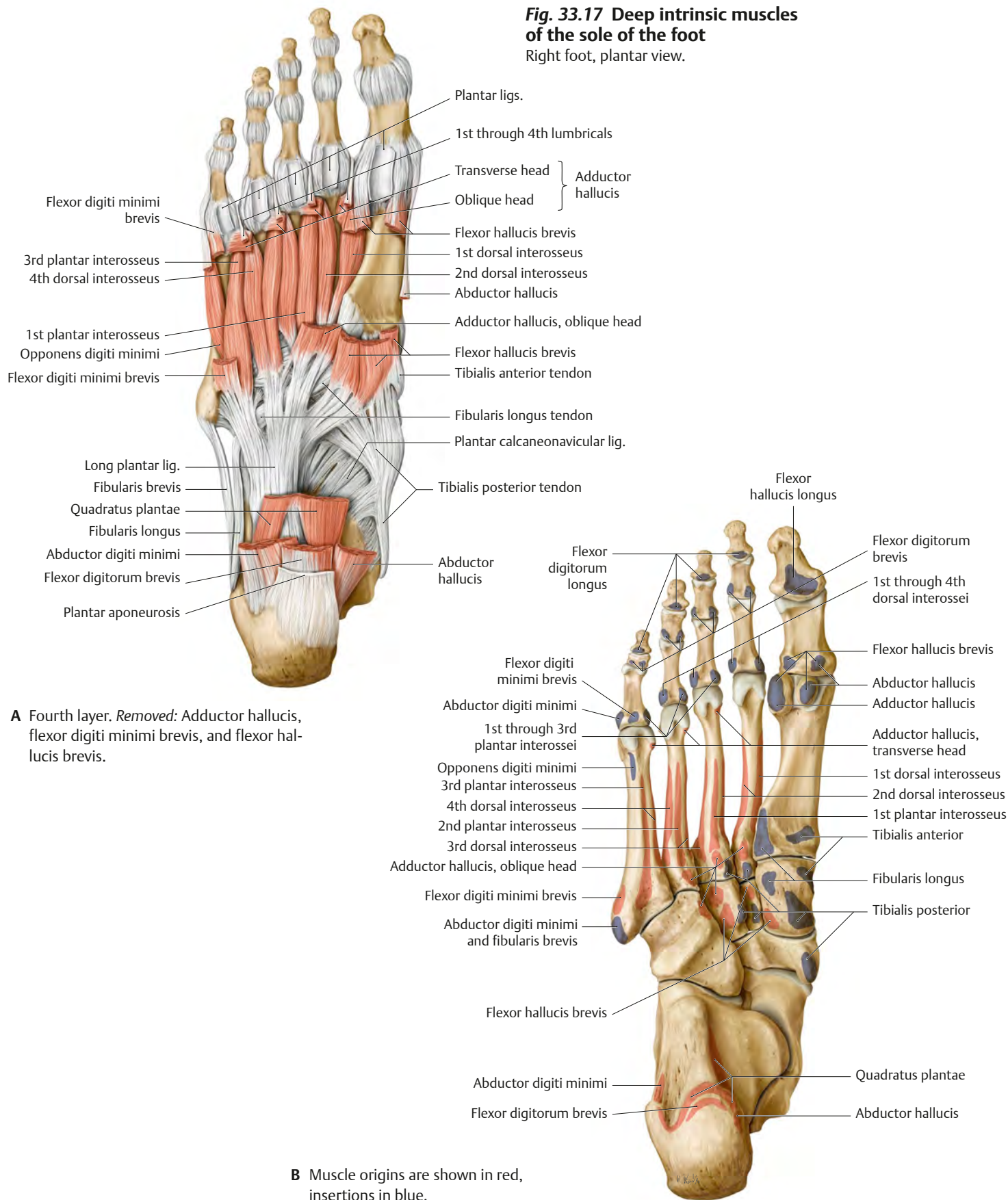
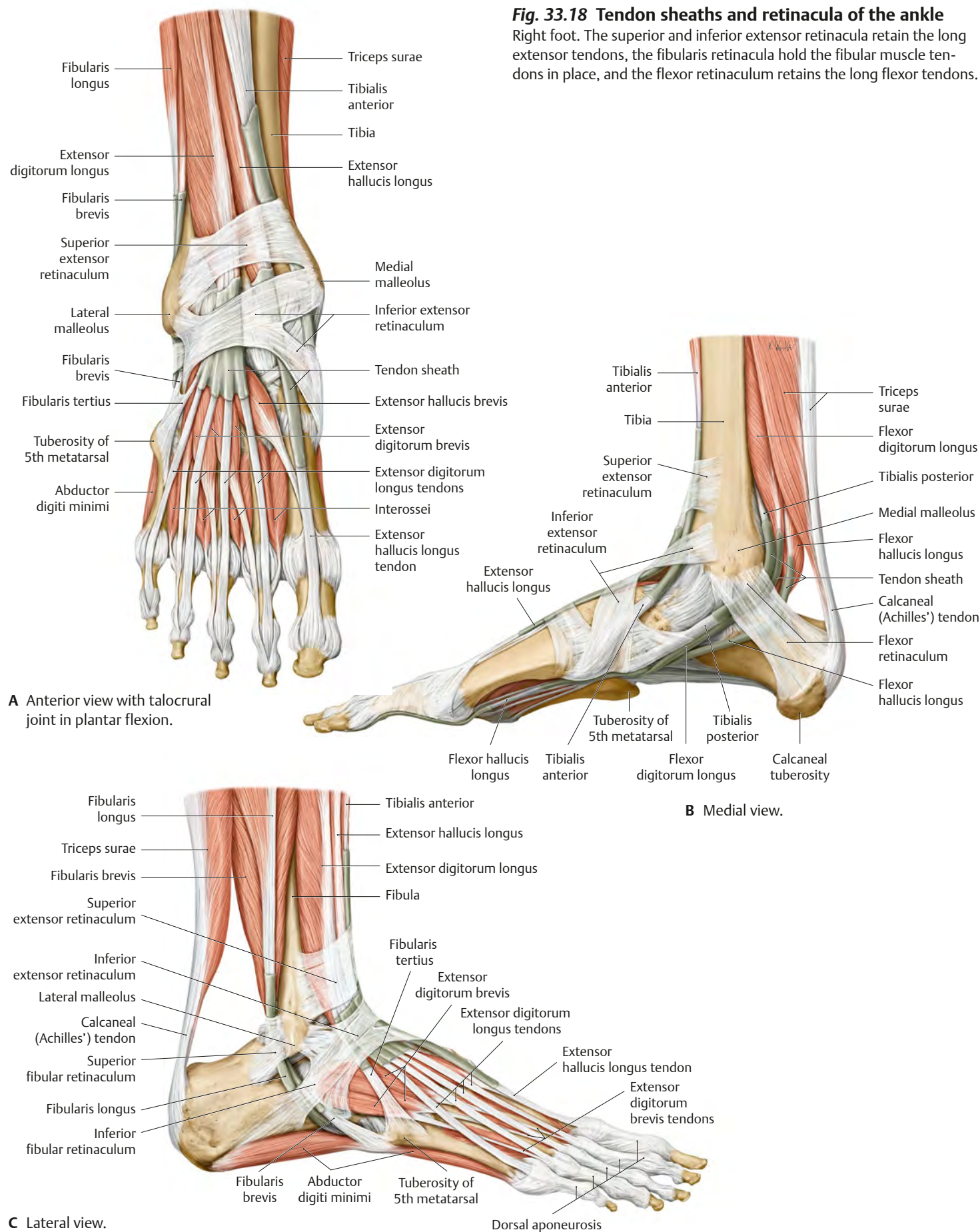


Fig. 33.18 Tendon sheaths and retinacula of the ankle

Right foot. The superior and inferior extensor retinacula retain the long extensor tendons, the fibularis retinacula hold the fibular muscle tendons in place, and the flexor retinaculum retains the long flexor tendons.

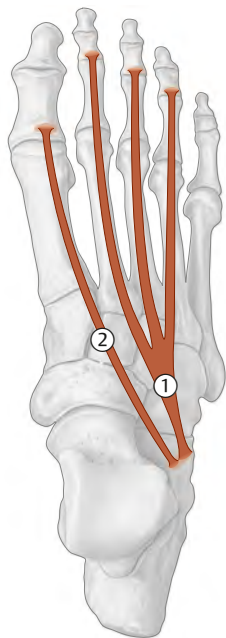


Muscle Facts (I)

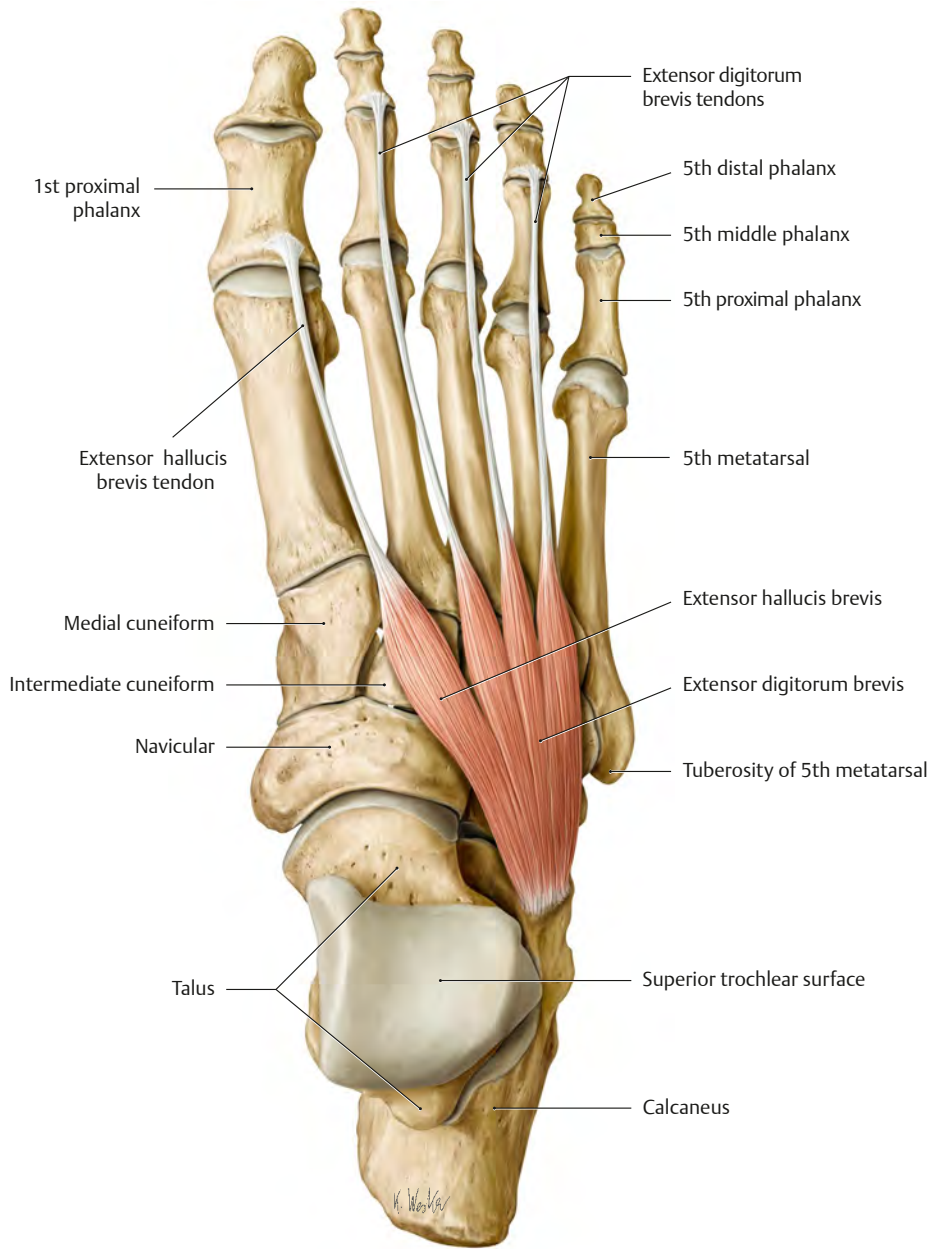
The dorsal surface (dorsum) of the foot contains only two muscles, the extensor digitorum brevis and the extensor hallucis brevis. The sole of

the foot, however, is composed of four complex layers that maintain the arches of the foot.

Fig. 33.19 Intrinsic muscles of the dorsum of the foot
Right foot, dorsal view.



A Schematic.

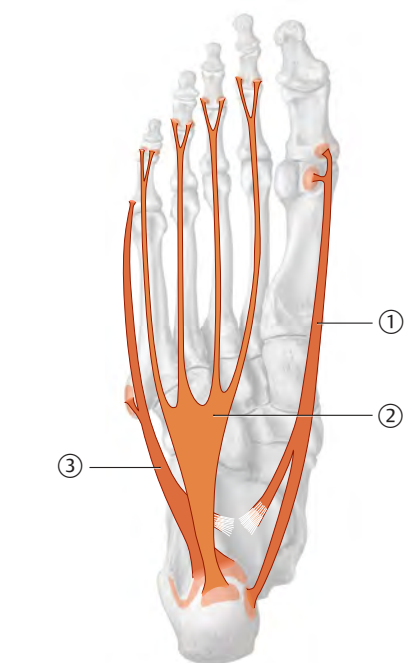


B Dorsal muscles of the foot.

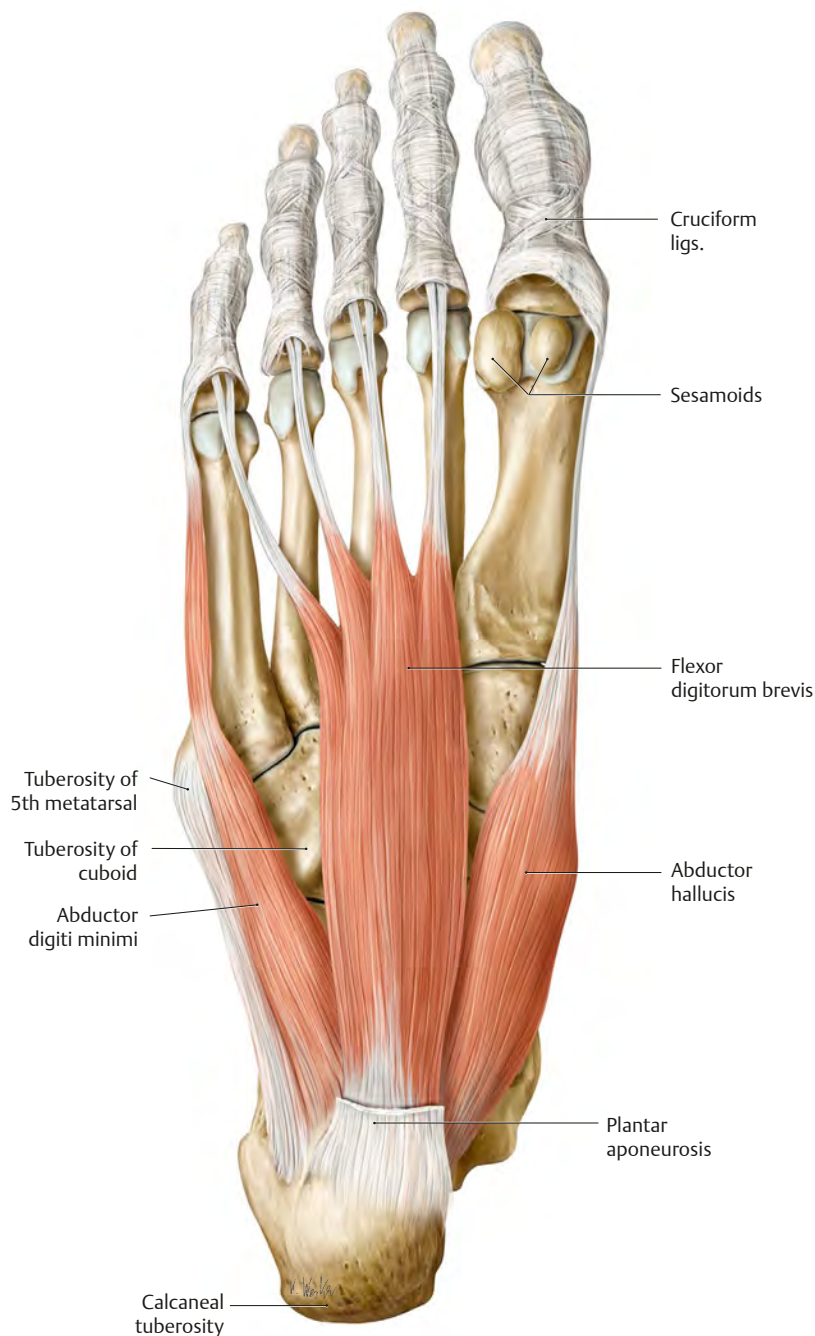
Table 33.2 Intrinsic muscles of the dorsum of the foot				
Muscle	Origin	Insertion	Innervation	Action
① Extensor digitorum brevis	Calcaneus (dorsal surface)	2nd to 4th toes (at dorsal aponeuroses and bases of the middle phalanges)	Deep fibular n. (L5, S1)	Extension of the MTP and PIP joints of the 2nd to 4th toes
② Extensor hallucis brevis		1st toe (at dorsal aponeurosis and proximal phalanx)		Extension of the MTP joints of the 1st toe
MTP, metatarsophalangeal; PIP, proximal interphalangeal.				

Fig. 33.20 Superficial intrinsic muscles of the sole of the foot

Right foot, plantar view.



A First layer, schematic.



B Intrinsic muscles of the sole, first layer.

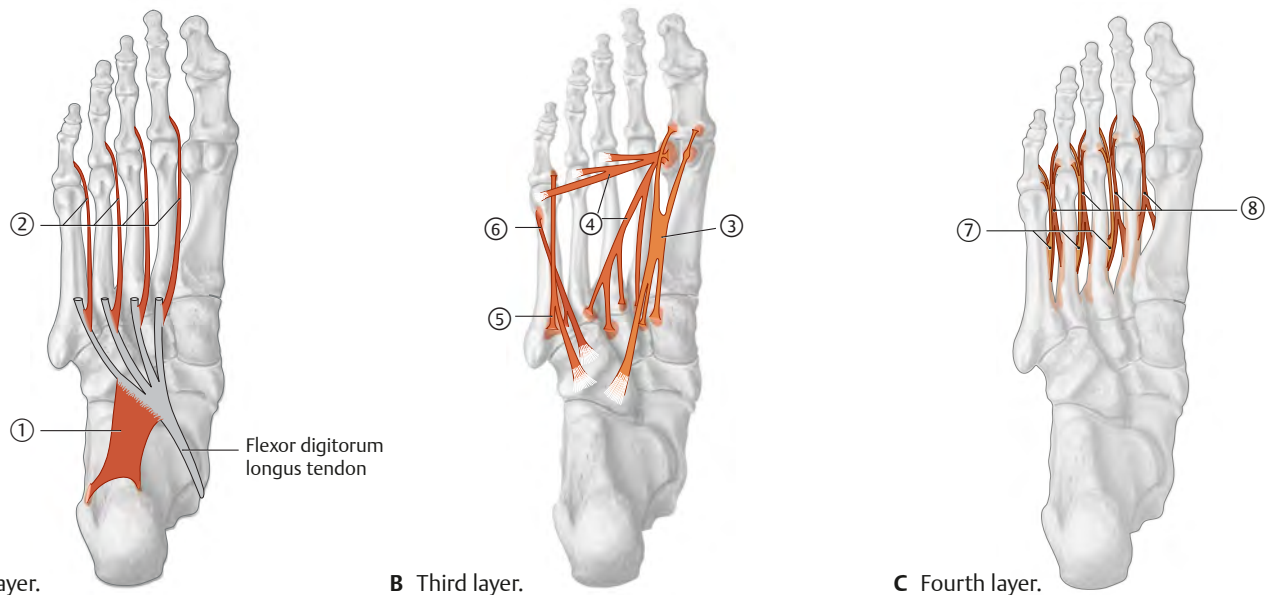
Table 33.3 Superficial intrinsic muscles of the sole of the foot

Muscle	Origin	Insertion	Innervation	Action
① Abductor hallucis	Calcaneal tuberosity (medial process); flexor retinaculum, plantar aponeurosis	1st toe (base of proximal phalanx via the medial sesamoid)	Medial plantar n. (S1, S2)	• 1st MTP joint: flexion and abduction of the 1st toe • Supports the longitudinal arch
② Flexor digitorum brevis	Calcaneal tuberosity (medial tubercle), plantar aponeurosis	2nd to 5th toes (sides of middle phalanges)		• Flexes the MTP and PIP joints of the 2nd to 5th toes • Supports the longitudinal arch
③ Abductor digiti minimi		5th toe (base of proximal phalanx), 5th metatarsal (at tuberosity)	Lateral plantar n. (S1–S3)	• Flexes the MTP joint of the 5th toe • Abducts the 5th toe • Supports the longitudinal arch

MTP, metatarsophalangeal; PIP, proximal interphalangeal.

Muscle Facts (II)

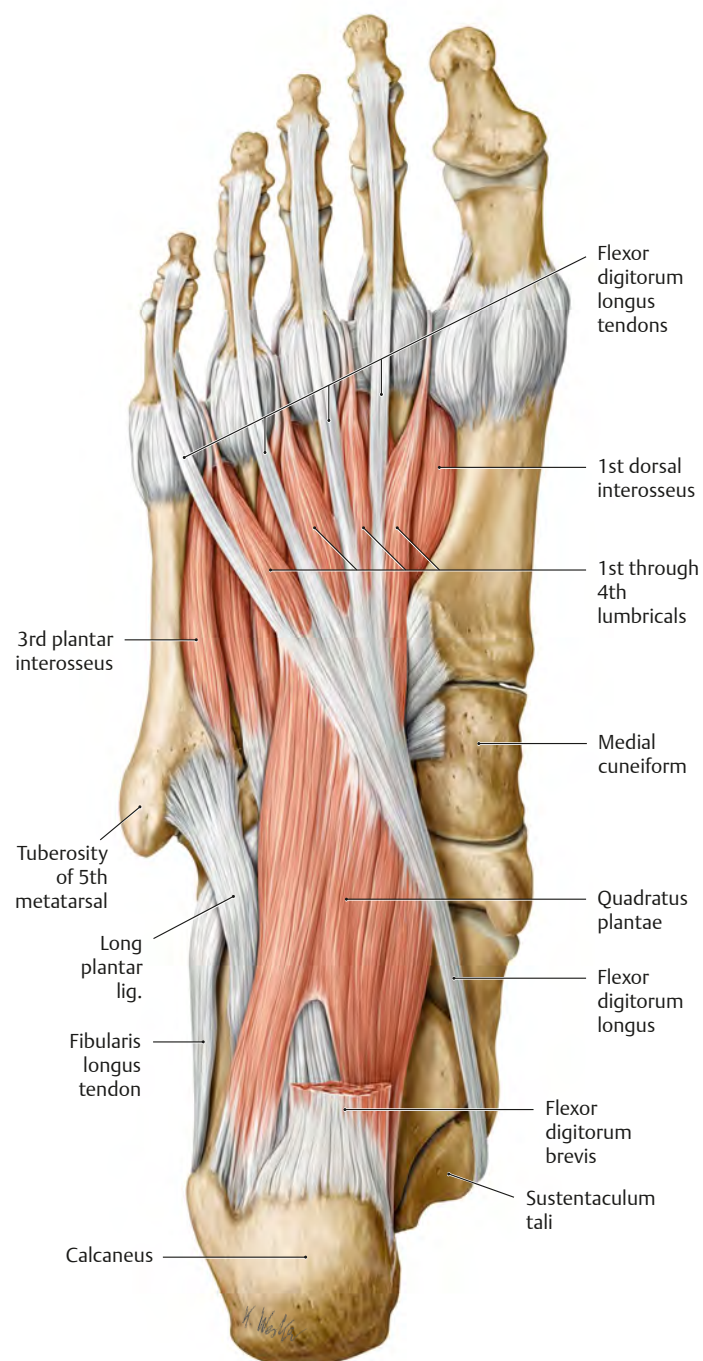
Fig. 33.21 Deep intrinsic muscles of the sole of the foot
Right foot, plantar view, schematics.



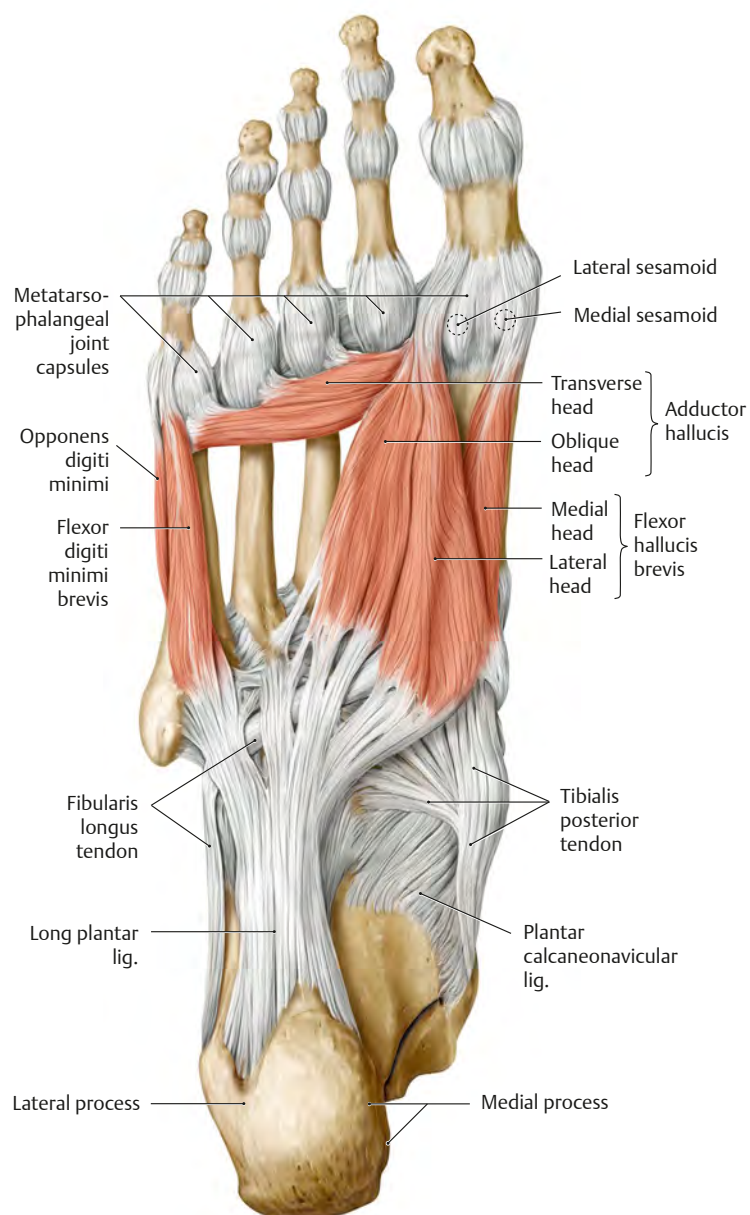
Muscle	Origin	Insertion	Innervation	Action
① Quadratus plantae	Calcaneal tuberosity (medial and plantar borders on plantar side)	Flexor digitorum longus tendon (lateral border)	Lateral plantar n. (S1–S3)	Redirects and augments the pull of flexor digitorum longus
② Lumbricals (four muscles)	Flexor digitorum longus tendons (medial borders)	2nd to 5th toes (at dorsal aponeuroses)	1st lumbrical: medial plantar n. (S2, S3) 2nd to 4th lumbrical: lateral plantar n. (S2, S3)	- Flexes the MTP joints of 2nd to 5th toes - Extension of IP joints of 2nd to 5th toes - Adducts 2nd to 5th toes toward the big toe
③ Flexor hallucis brevis	Cuboid, lateral cuneiforms, and plantar calcaneocuboid lig.	1st toe (at base of proximal phalanx via medial and lateral sesamoids)	Medial head: medial plantar n. (S1, S2) Lateral head: lateral plantar n. (S1, S2)	- Flexes the first MTP joint - Supports the longitudinal arch
④ Adductor hallucis	Oblique head: 2nd to 4th metatarsals (at bases) cuboid and lateral cuneiforms Transverse head: MTP joints of 3rd to 5th toes, deep transverse metatarsal lig.	1st proximal phalanx (at base, by a common tendon via the lateral sesamoid)	Lateral plantar n., deep branch (S2, S3)	- Flexes the first MTP joint - Adducts big toe - Transverse head: supports transverse arch - Oblique head: supports longitudinal arch
⑤ Flexor digiti minimi brevis	5th metatarsal (base), long plantar lig.	5th toe (base of proximal phalanx)	Lateral plantar n., superficial branch (S2, S3)	Flexes the MTP joint of the little toe
⑥ Opponens digiti minimi*	Long plantar lig.; fibularis longus (at plantar tendon sheath)	5th metatarsal		Pulls 5th metatarsal in plantar and medial direction
⑦ Plantar interossei (three muscles)	3rd to 5th metatarsals (medial border)	3rd to 5th toes (medial base of proximal phalanx)		- Flexes the MTP joints of 3rd to 5th toes - Extension of IP joints of 3rd to 5th toes - Adducts 3rd to 5th toes toward 2nd toe
⑧ Dorsal interossei (four muscles)	1st to 5th metatarsals (by two heads on opposing sides)	1st interosseus: 2nd proximal phalanx (medial base) 2nd to 4th interossei: 2nd to 4th proximal phalanges (lateral base), 2nd to 4th toes (at dorsal aponeuroses)	Lateral plantar n. (S2, S3)	- Flexes the MTP joints of 2nd to 4th toes - Extension of IP joints of 2nd to 4th toes - Abducts 3rd and 4th toes from 2nd toe

IP, interphalangeal; MTP, metatarsophalangeal. *May be absent.

Fig. 33.22 Deep intrinsic muscles of the sole of the foot
Right foot, plantar view.



A Intrinsic muscles of the sole, second and fourth layers.



B Intrinsic muscles of the sole, third layer.

Lower Limb



Lower Limb



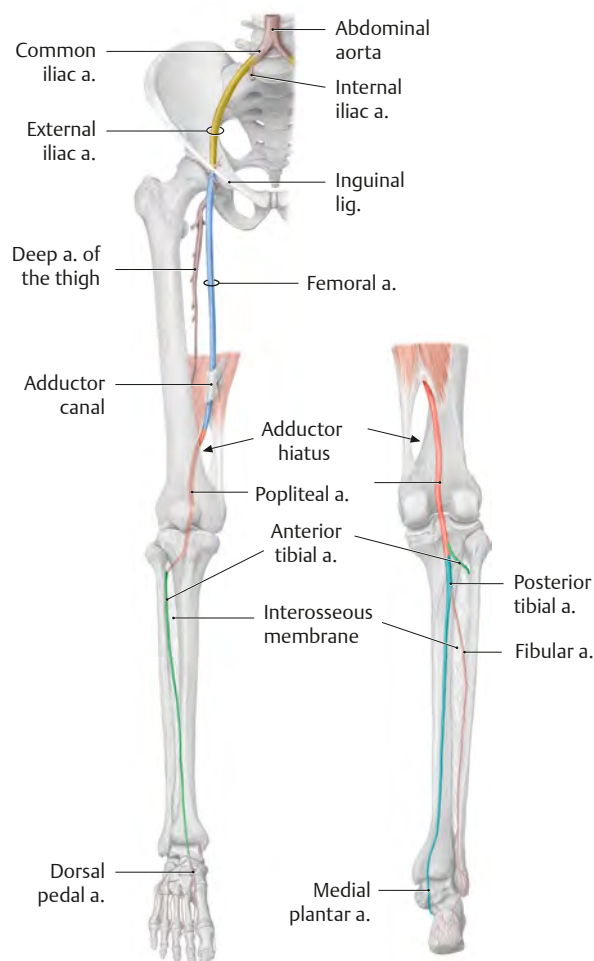
Lower Limb



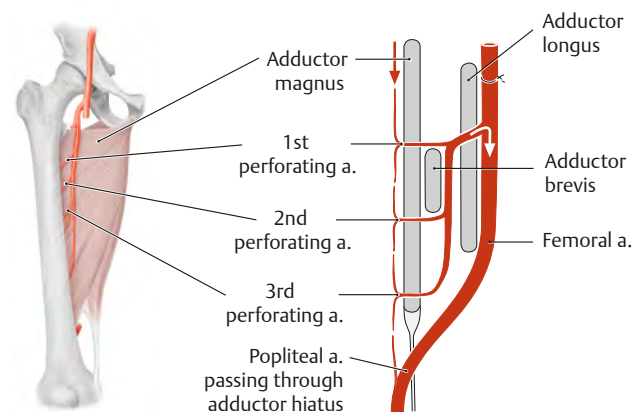
Lower Limb

Fig. 34.2 Segments of the femoral artery

The blood supply to the lower limbs originates from the femoral artery. Color is used to identify the named distal segments of this vessel.

**Fig. 34.3 Deep artery of the thigh**

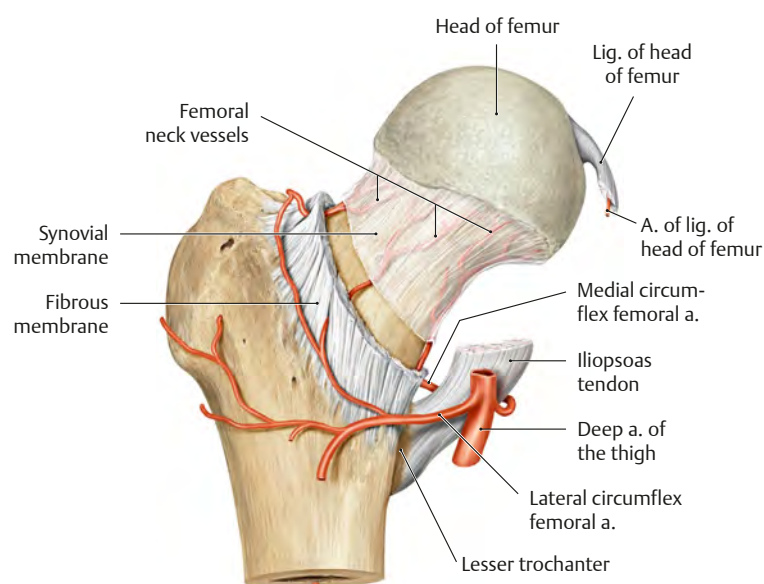
Right leg. The artery passes posteriorly through the adductor muscles of the medial thigh to supply the muscles of the posterior compartment via three to five perforating branches. Ligation of the femoral artery proximal to the origin of the deep artery of the thigh (left) is well tolerated owing to the collateral blood supply (arrows) from branches of the internal iliac artery that anastomose with the perforating branches.

**Clinical box 34.1****Femoral head necrosis**

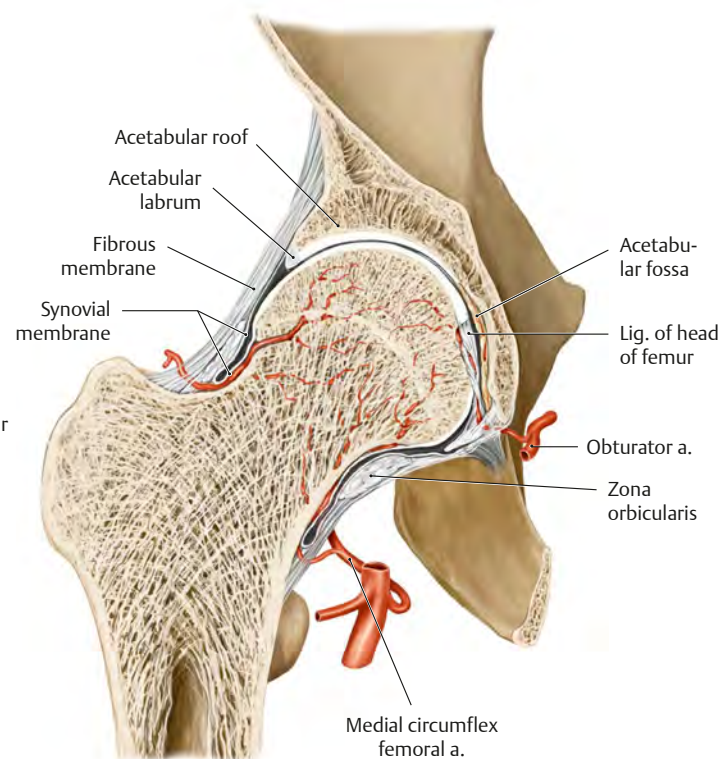
Dislocation or fracture of the femoral head (e.g., in patients with osteoporosis) may tear the femoral neck vessels, resulting in femoral head necrosis.

Fig. 34.4 Arteries of the femoral head

Anterior view.



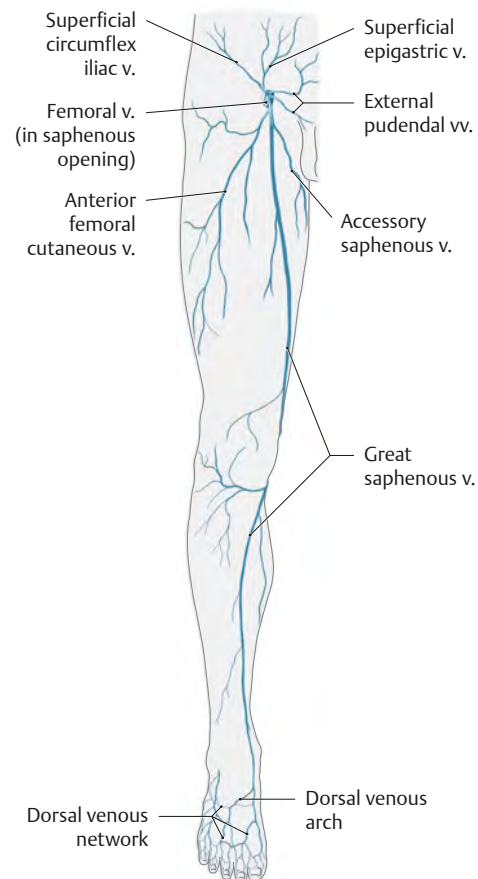
A Right femur.



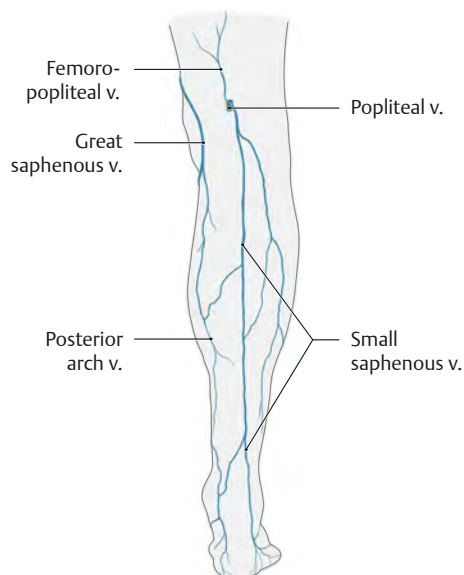
B Right femur, coronal section.

Veins & Lymphatics of the Lower Limb

Fig. 34.5 Superficial (epifascial) veins of the lower limb

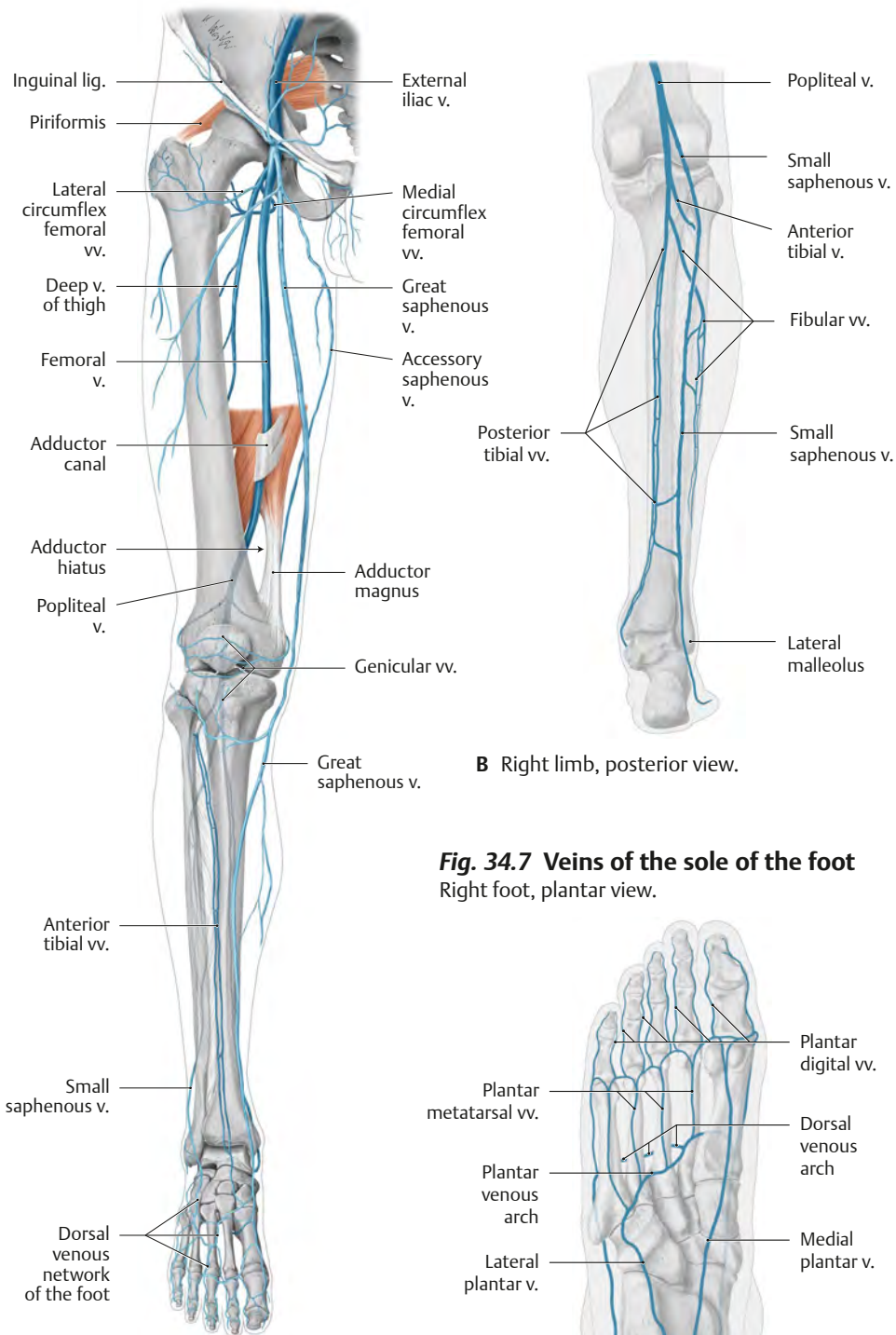


A Right limb, anterior view.



B Right limb, posterior view.

Fig. 34.6 Deep veins of the lower limb



A Right limb, anterior view.

Fig. 34.7 Veins of the sole of the foot
Right foot, plantar view.

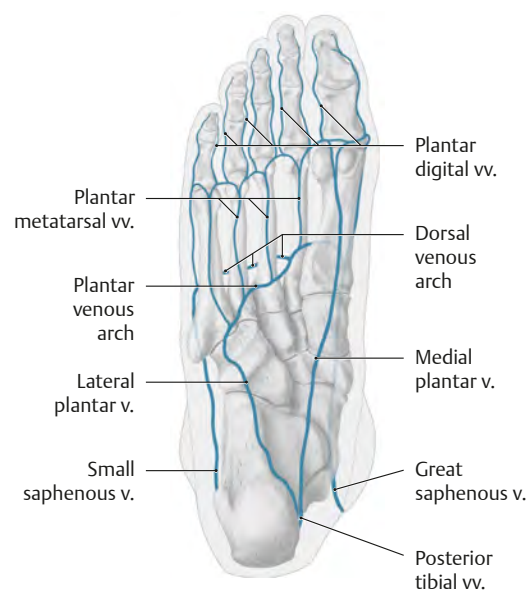


Fig. 34.8 Clinically important perforating veins

Right leg, medial view.

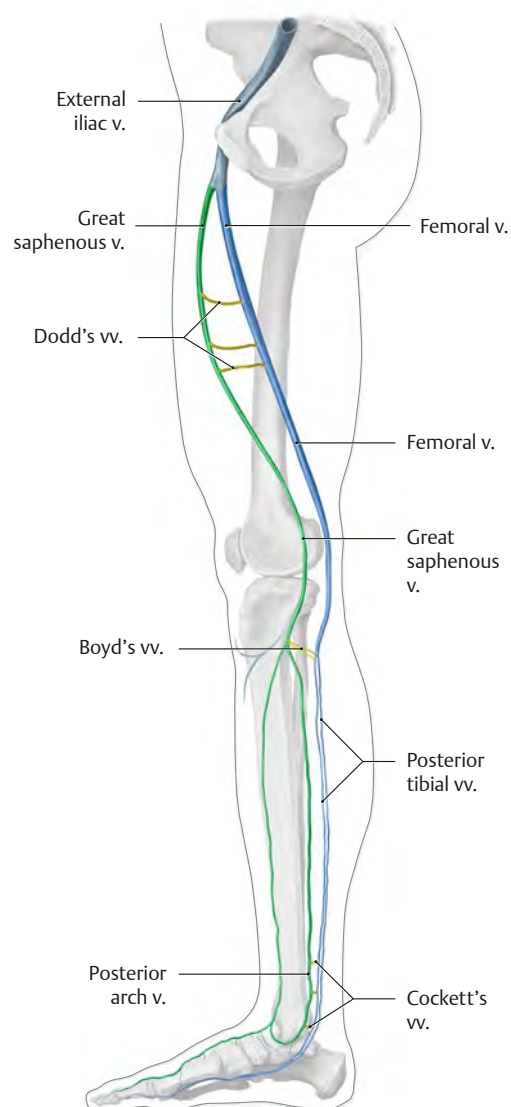


Fig. 34.9 Superficial lymph nodes

Right limb. Arrows indicate the main directions of lymphatic drainage.

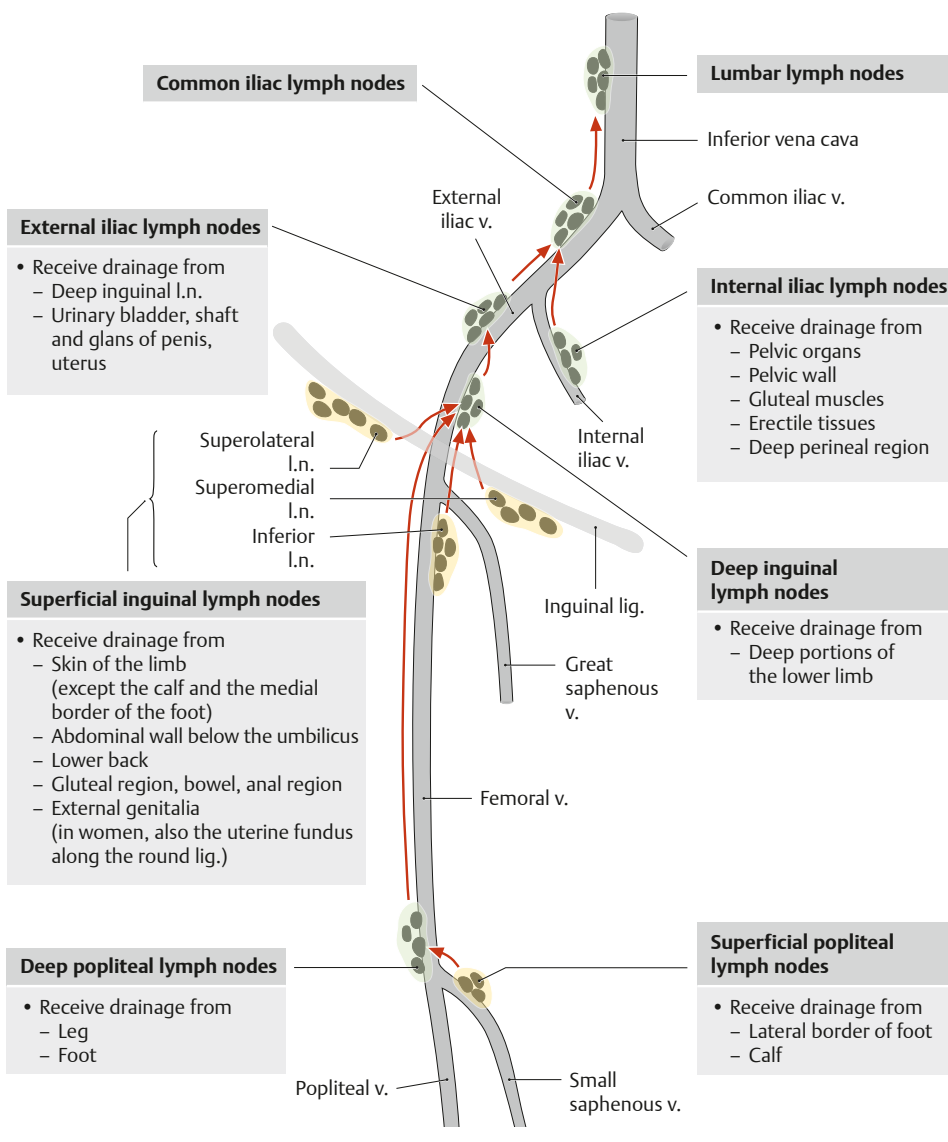
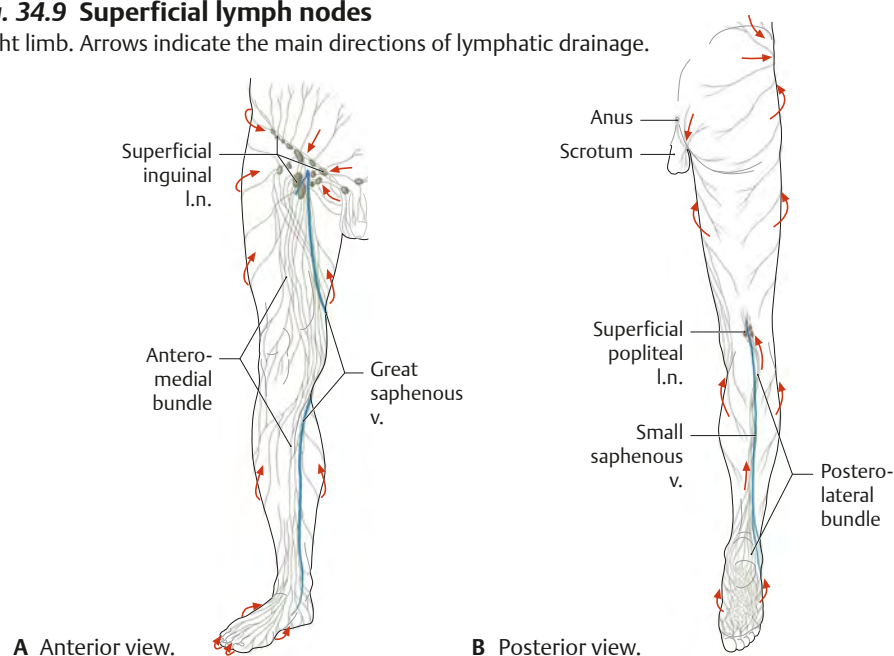


Fig. 34.10 Lymph nodes and lymphatic drainage

Right limb, anterior view. Arrows indicate direction of lymphatic drainage. Yellow shading: superficial nodes; green shading: deep nodes.

Lumbosacral Plexus

The lumbosacral plexus supplies sensory and motor innervation to the lower limb. It is formed by the anterior (ventral) rami of the lumbar and sacral spinal nerves, with contributions from the subcostal nerve (T12) and coccygeal nerve (Co1). The lumbar plexus mainly supplies the

anterior and medial parts of the thigh with a small contribution to the medial leg. The sacral plexus supplies the posterior thigh and most of the leg and foot.

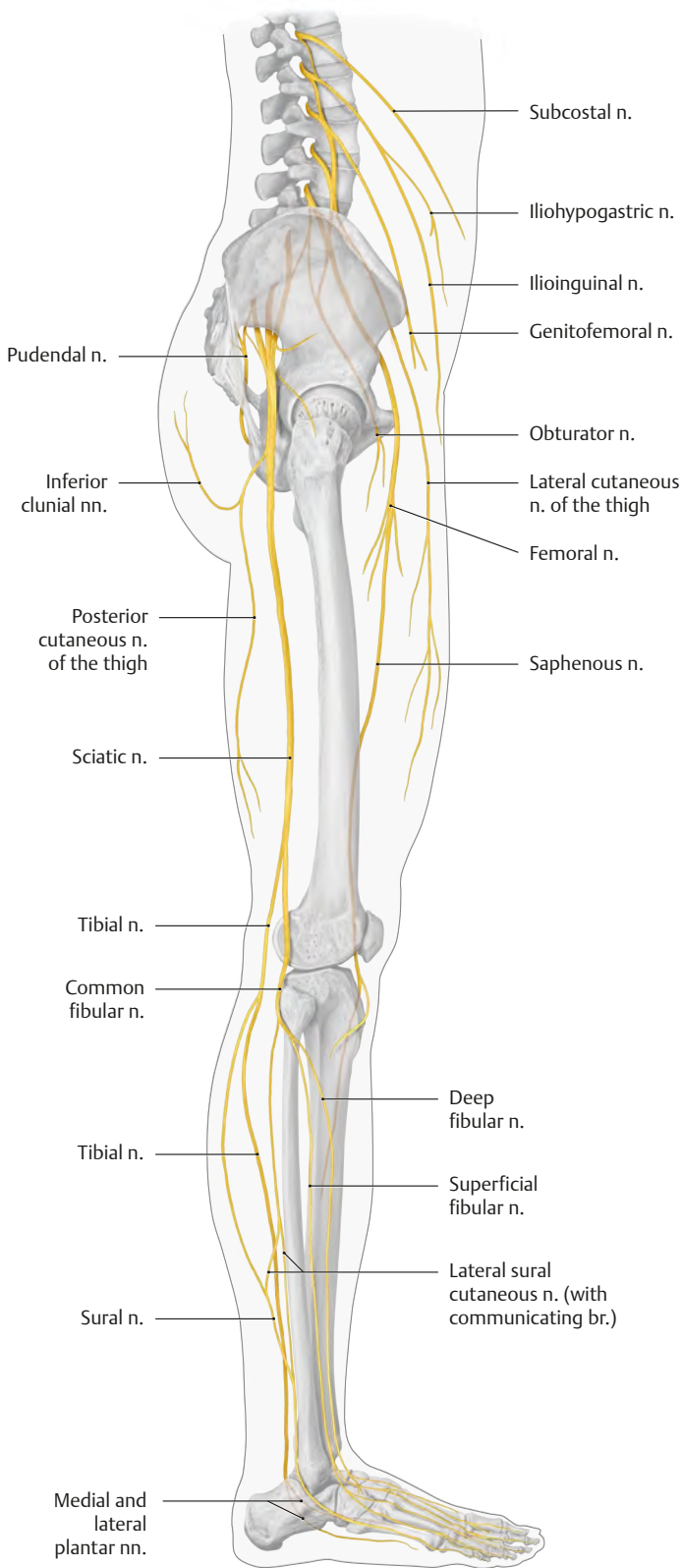
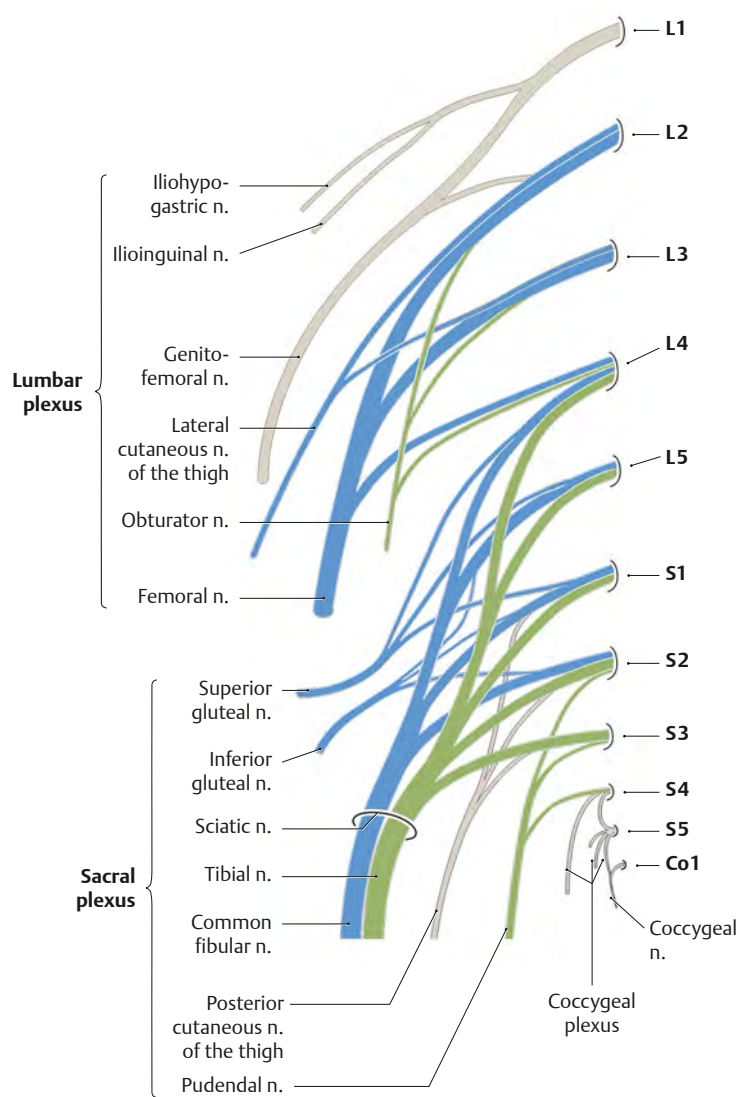


Table 34.1 Nerves of the lumbosacral plexus			
Lumbar plexus			
Iliohypogastric n.	L1	p. 479	
Ilioinguinal n.	L1		
Genitofemoral n.	L1–L2		
Lateral cutaneous n. of the thigh	L2–L3	p. 480	
Obturator n.	L2–L4		
Femoral n.		p. 481	
Sacral plexus			
Superior gluteal n.	L4–S1	p. 483	
Inferior gluteal n.	L5–S2	p. 482	
Posterior cutaneous n. of the thigh	S1–S3		
Sciatic n.	Common fibular n.	L4–S2	p. 484
	Tibial n.	L4–S3	p. 485
Pudendal n.	S2–S4	pp. 284–285	

Clinical box 34.2

Injuries to nerves of the lumbar and sacral plexuses

Similar to nerve injuries of the upper limb, injuries involving nerves of the lumbosacral plexus are best understood through an appreciation of the plexus organization. The lumbar plexus arises from higher levels (L1–L4) of the spinal cord and supplies muscles of the abdominal wall and anterior and medial thigh. The sacral plexus arises from lower levels (L4–S4) of the spinal cord and supplies the perineum and, via the large sciatic nerve, the posterior thigh, entire leg and most of the foot. Nerves of the lumbar and sacral plexuses are less likely to be injured at the root level than those of the brachial plexus, although exceptions to this are the obturator and femoral nerves that may be compromised by herniation of intervertebral disks at L4 or L5 as they pass through the intervertebral foramina. Peripheral nerve injuries, such as that of the common fibular nerve, can occur in places where the nerve is superficial and passes close to a bony prominence.

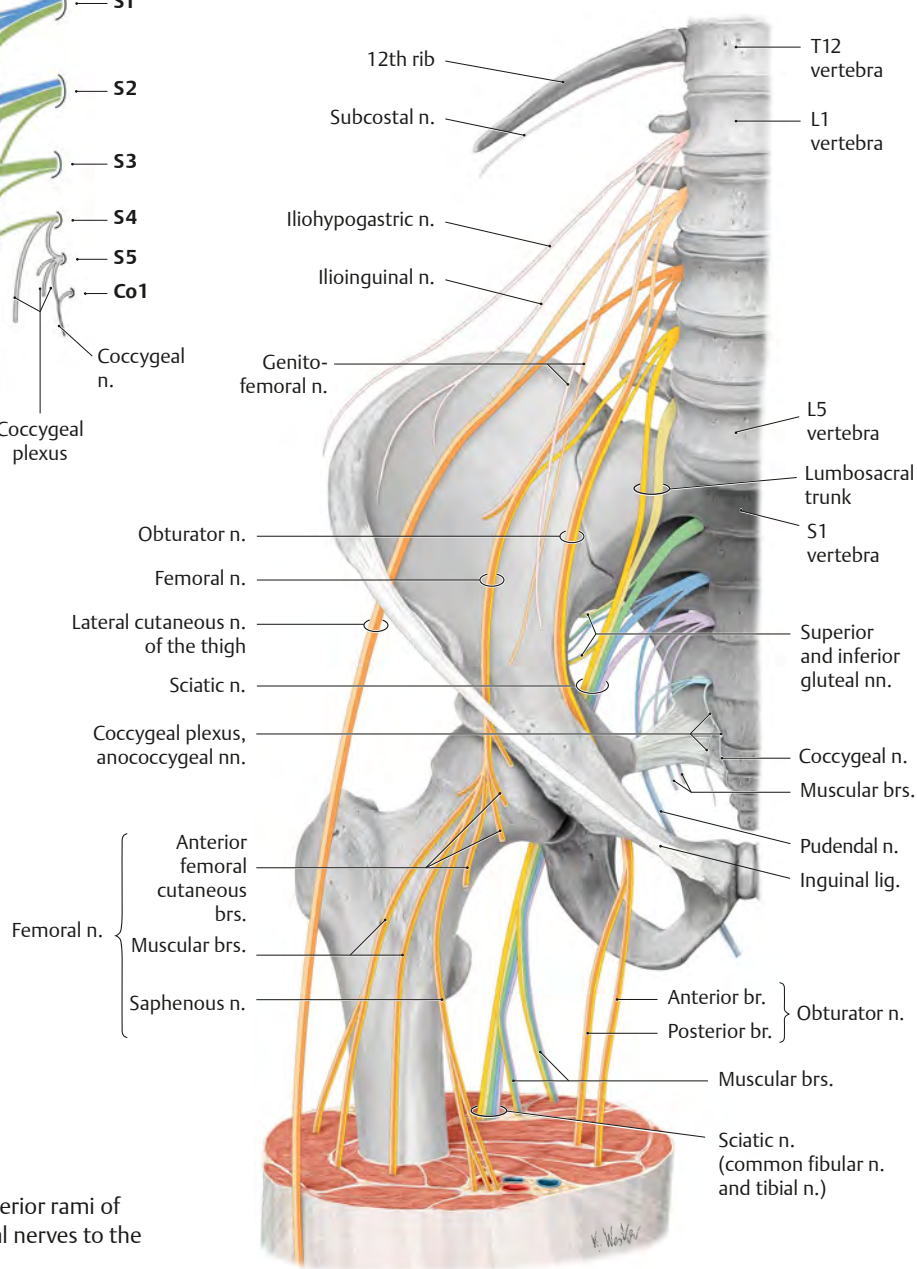


A Structure of the lumbosacral plexus.

Fig. 34.11 Lumbosacral plexus

Right side, anterior view.

Spinal nerve contributions to nerves of the lumbar and sacral plexuses. Separation of the anterior rami into anterior and posterior divisions are not as neatly demarcated in the lumbosacral plexus as they are in the brachial plexus of the upper limb. Where clearly separated into nerves they are indicated as: green = anterior division, blue = posterior division. Note: Nerves of the sacral plexus not shown: n. to piriformis (S1, S2), n. to obturator internus (L5, S1), and n. to quadratus femoris (L5, S1).



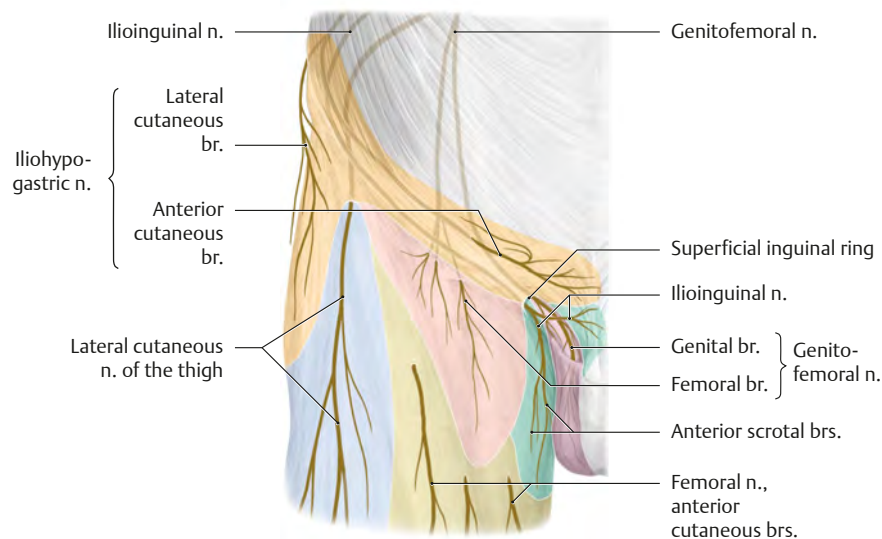
B Course of the lumbosacral plexus. Distribution of anterior rami of lumbar (yellow/orange) and sacral (blue/green) spinal nerves to the gluteal region and lower limb.

Nerves of the Lumbar Plexus

Table 34.2 Nerves of the lumbar plexus			
Nerve	Level	Innervated muscle	Cutaneous branches
Iliohypogastric n.	L1	Transversus abdominis and internal oblique (inferior portions)	Anterior and lateral cutaneous brs.
Ilioinguinal n.	L1		♂: Anterior scrotal nn. ♀: Anterior labial nn.
Genitofemoral n.	L1–L2	♂: Cremaster (genital br.)	Genital br. Femoral br.
Lateral cutaneous n. of the thigh	L2–L3	—	lateral cutaneous n. of the thigh
Obturator n.	L2–L4	See p. 480	
Femoral n.	L2–L4	See p. 481	
Short, direct muscular brs.	T12–L4	Psoas major Quadratus lumborum Iliacus Intertransversarii lumborum	—

Fig. 34.12 Cutaneous innervation of the inguinal region

Right male inguinal region, anterior view.



Clinical box 34.3

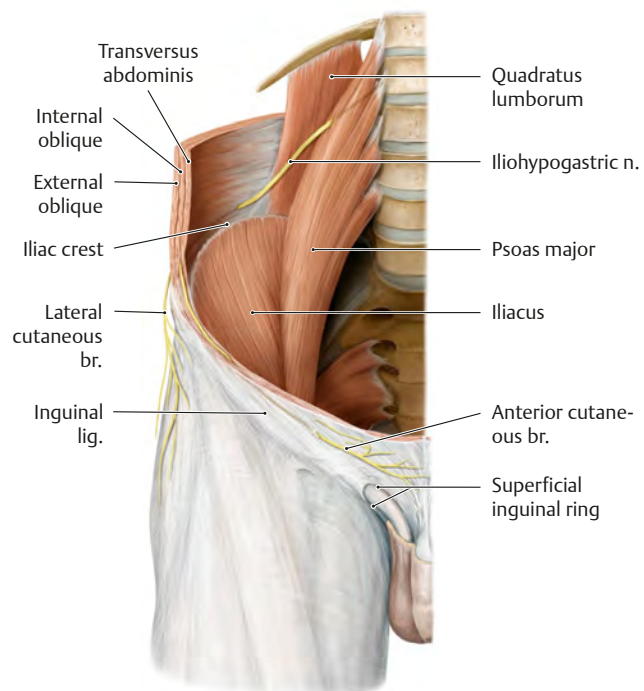
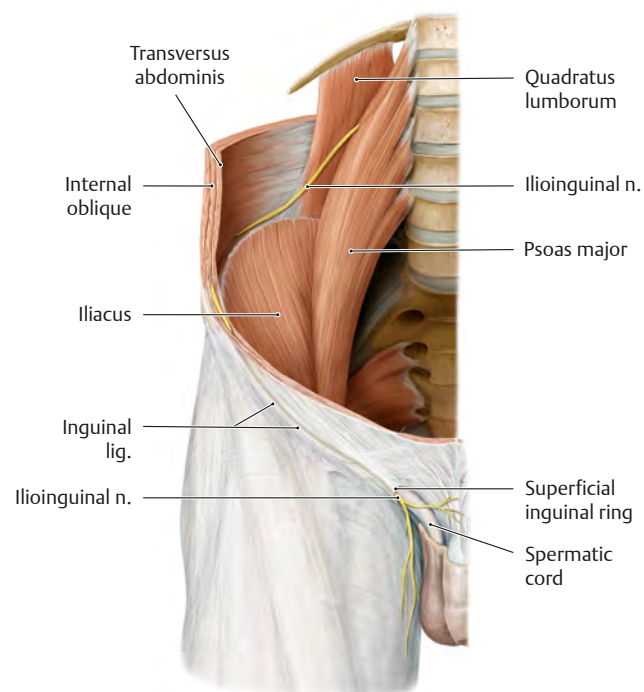
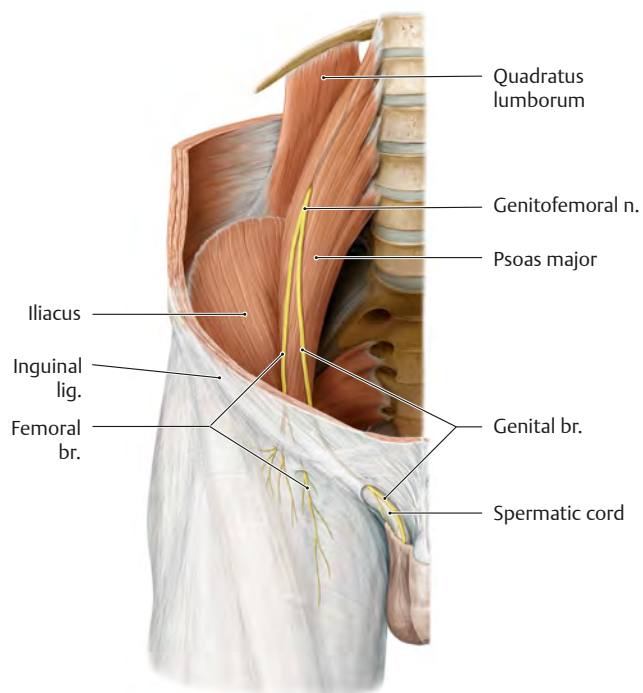
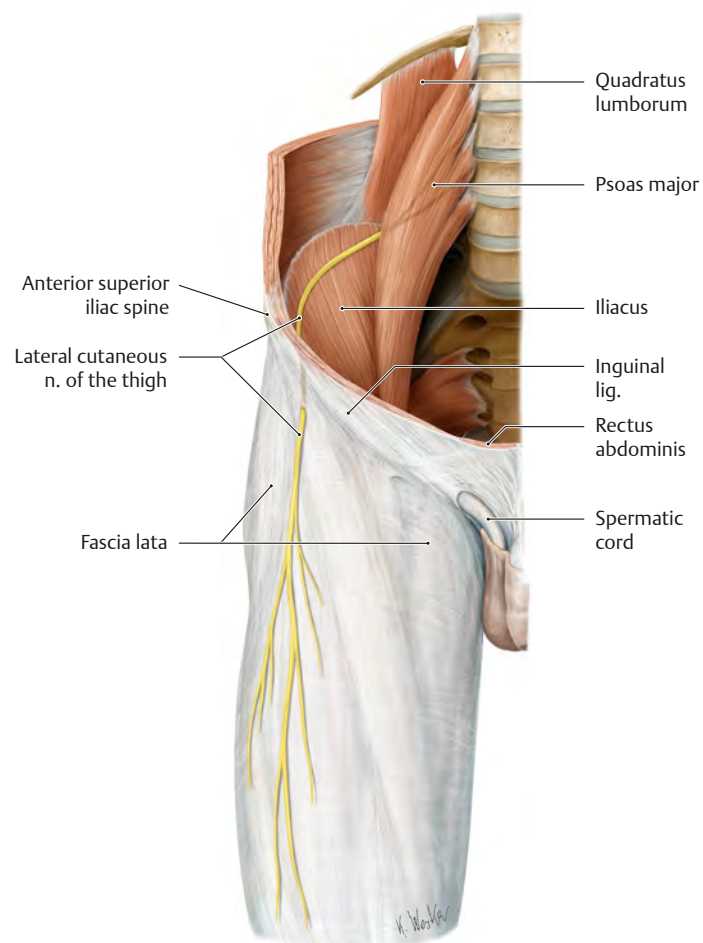
Entrapment of the lateral femoral cutaneous nerve (meralgia paresthetica)

Ischemia (diminished blood flow) of the lateral cutaneous nerve of the thigh can result when the nerve is stretched or entrapped by the inguinal ligament (see Fig. 34.11B) during hyperextension of the hip or with increased lordosis (curvature) of the lumbar spine, as often occurs during pregnancy.

This results in pain, numbness, or paresthesia (tingling or burning) on the outer aspect of the thigh. It is most commonly found in obese or diabetic individuals and in pregnant women.

Fig. 34.13 Nerves of the lumbar plexus

Right side, anterior view with the anterior abdominal wall removed.

**A** Iliohypogastric nerve.**B** Ilioinguinal nerve.**C** Genitofemoral nerve.**D** Lateral cutaneous nerve of the thigh.

Nerves of the Lumbar Plexus: Obturator & Femoral Nerves

Fig. 34.14 Obturator nerve: Cutaneous distribution
Right leg, medial view.



Fig. 34.15 Obturator nerve
Right side, anterior view.

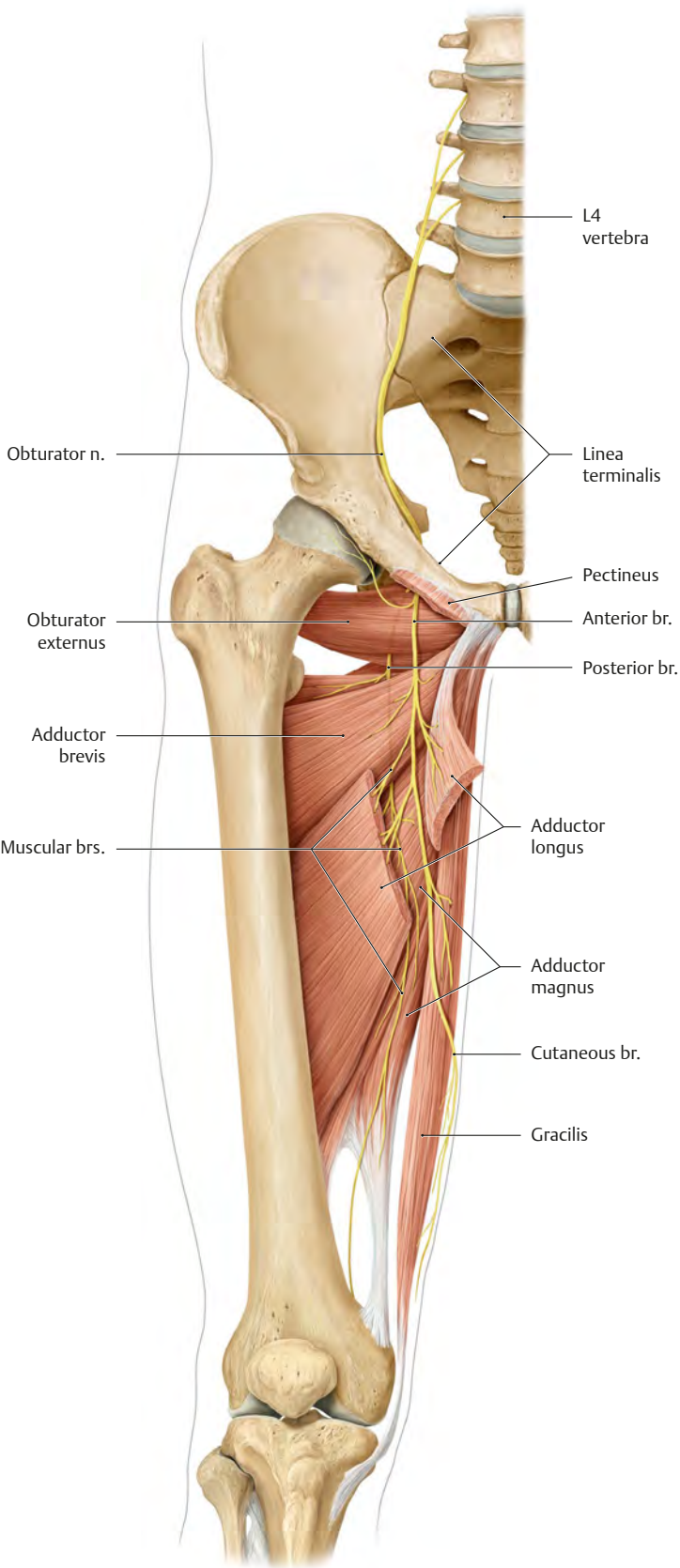


Table 34.3 Obturator nerve (L2–L4)	
Motor branches	Innervated muscles
Direct br. Anterior br.	Obturator externus
	Adductor longus
	Adductor brevis
	Gracilis
	Pectineus
Posterior br.	Adductor magnus
Sensory branches	
Cutaneous br.	

Fig. 34.16 Femoral nerve
Right side, anterior view.

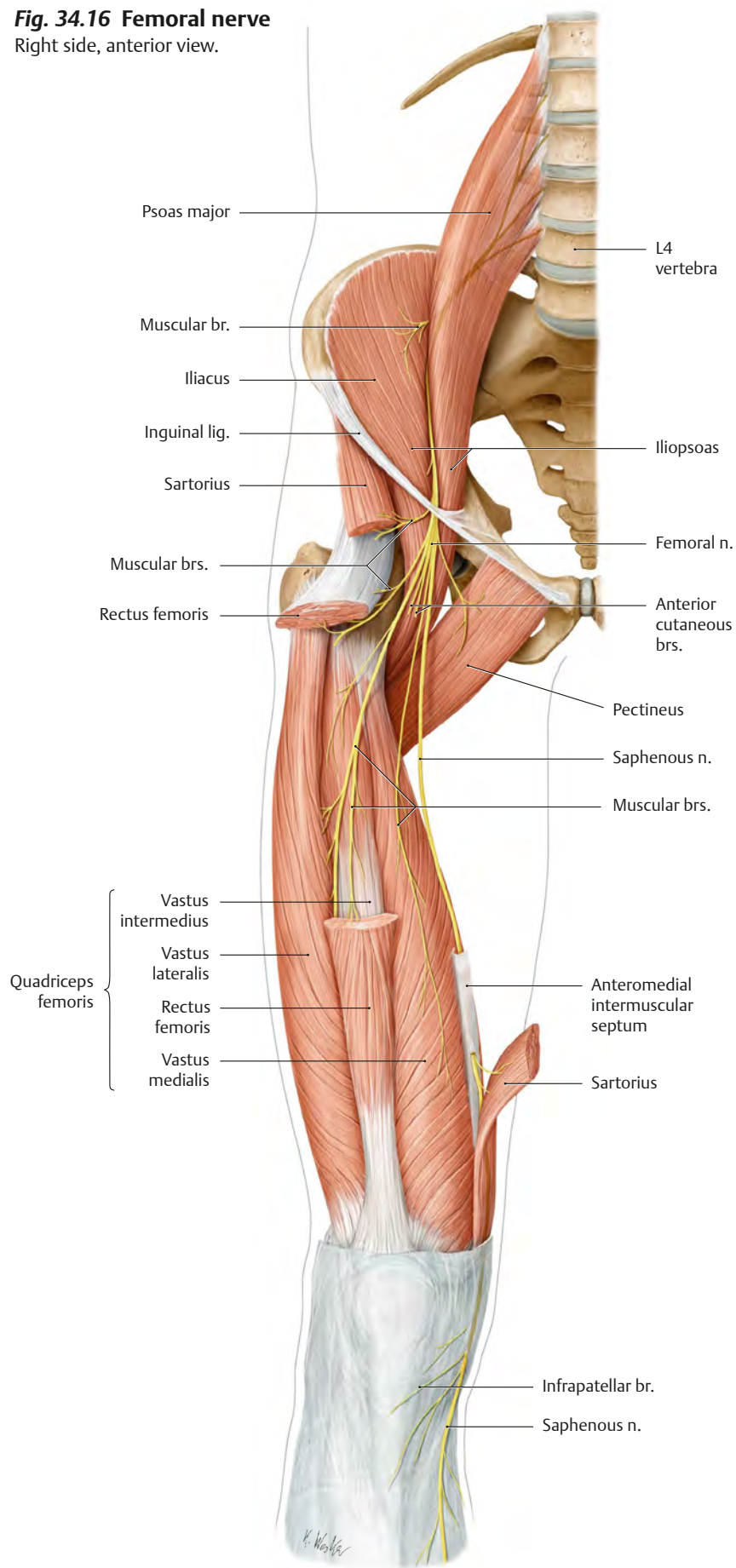


Fig. 34.17 Femoral nerve: Cutaneous distribution
Right limb, anterior view.

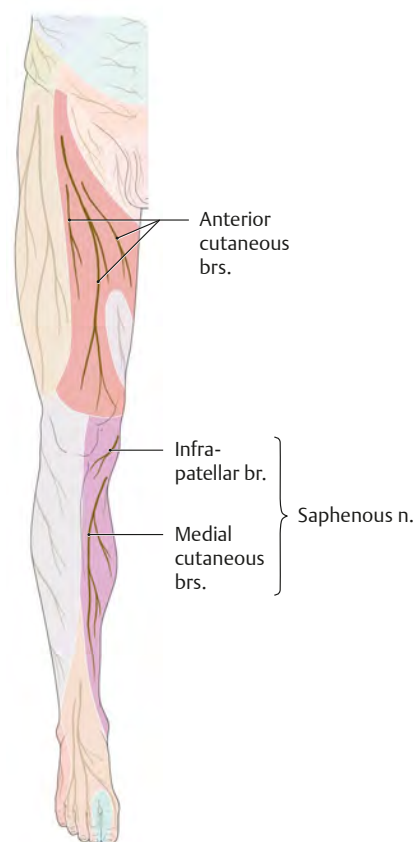


Table 34.4

Femoral nerve (L2–L4)

Motor branches	Innervated muscles
Muscular brs.	Iliopsoas
	Pectineus
	Sartorius
	Quadriceps femoris
Sensory branches	
Anterior cutaneous br.	
Saphenous n.	

Nerves of the Sacral Plexus

Table 34.5 Nerves of the sacral plexus				
Nerve		Level	Innervated muscle	Cutaneous branches
Superior gluteal n.		L4–S1	Gluteus medius Gluteus minimus Tensor fasciae latae	—
Inferior gluteal n.		L5–S2	Gluteus maximus	—
Posterior cutaneous n. of the thigh		S1–S3	—	Posterior cutaneous n. of the thigh
Direct branches	N. of piriformis	S1–S2	Piriformis	—
	N. of obturator internus	L5–S1	Obturator internus Gemelli	—
	N. of quadratus femoris		Quadratus femoris	—
Sciatic n.	Common fibular n.	L4–S2	See p. 484	
	Tibial n.	L4–S3	See p. 485	
Pudendal n.		S2–S4	See pp. 284–285	

Fig. 34.18 Cutaneous innervation of the gluteal region
Right limb, posterior view.

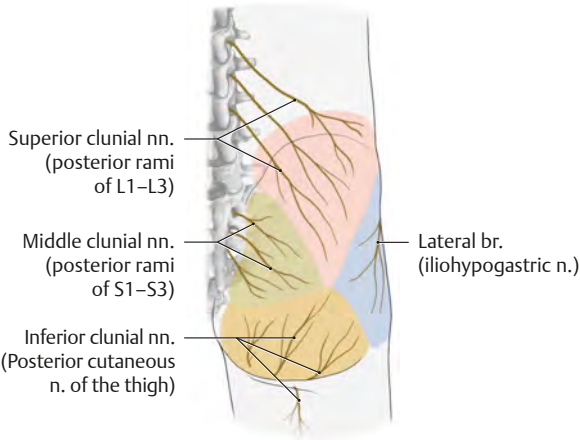


Fig. 34.20 Emerging spinal nerve
Horizontal section, superior view.

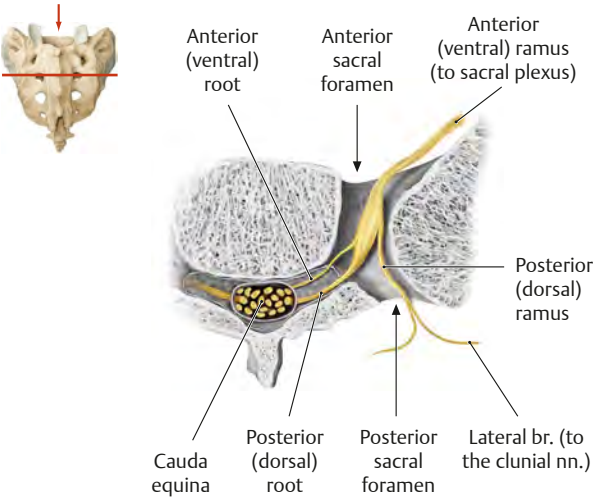


Fig. 34.19 Posterior cutaneous nerve of the thigh: Cutaneous distribution
Right limb, posterior view.

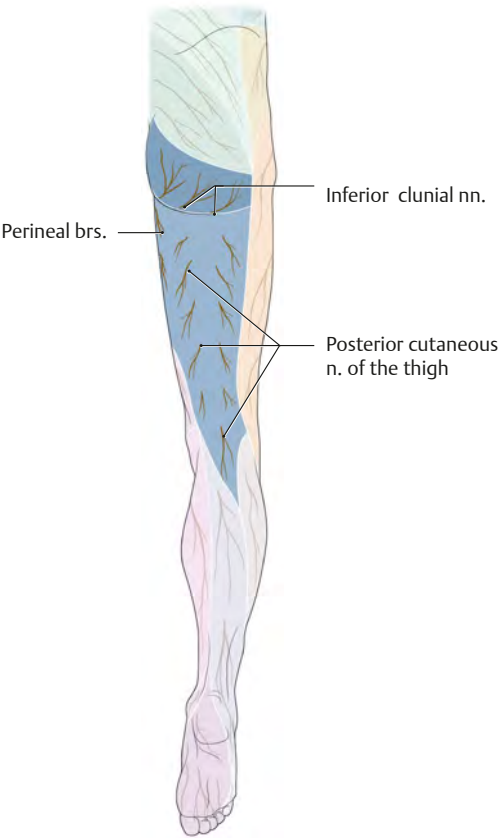
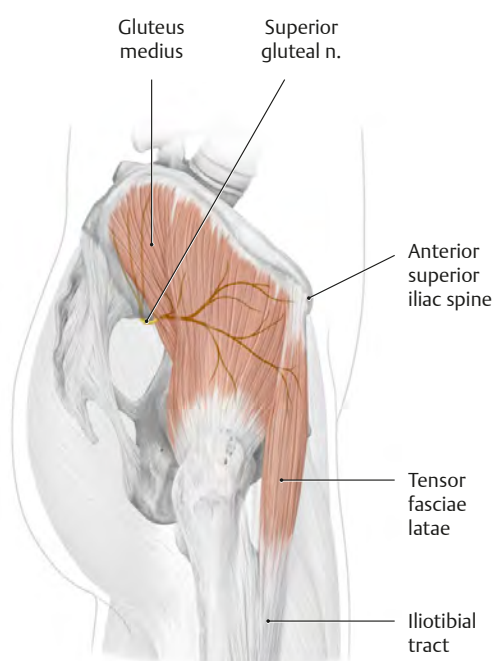
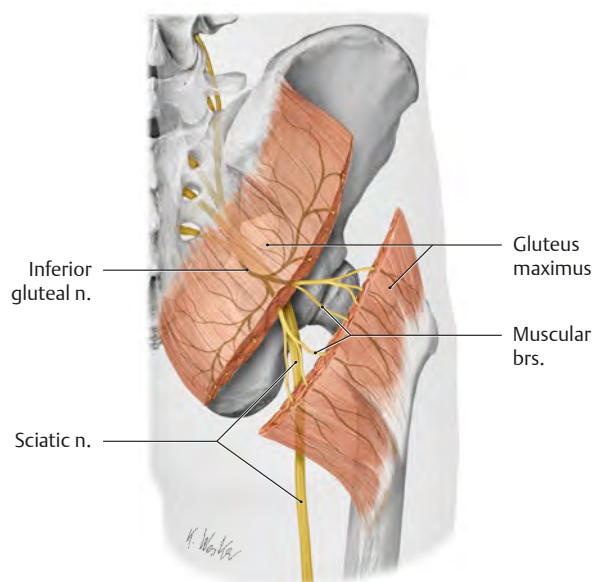


Fig. 34.21 Nerves of the sacral plexus
Right limb.



A Superior gluteal nerve. Lateral view.

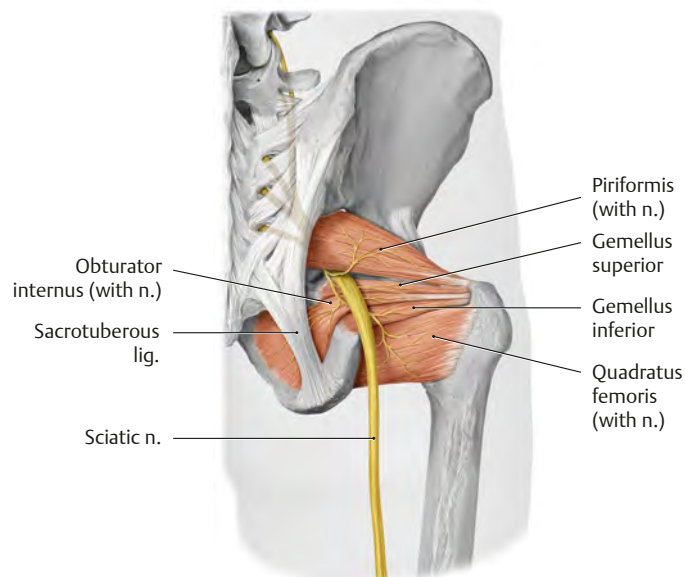
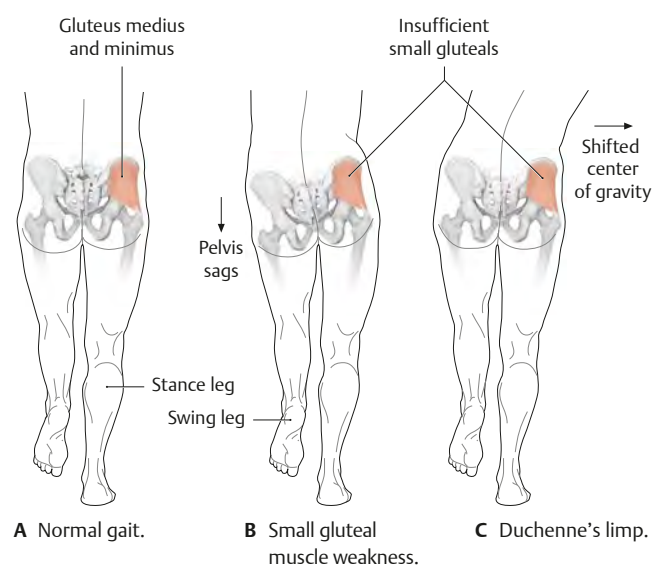


B Inferior gluteal nerve. Posterior view.

Clinical box 34.4

Small gluteal muscle weakness

The small gluteal muscles on the stance side stabilize the pelvis in the coronal plane (**A**). Weakness or paralysis of the small gluteal muscles from damage to the superior gluteal nerve (e.g., due to a faulty intramuscular injection) is manifested by weak abduction of the affected hip joint. In a positive Trendelenburg's test, the pelvis sags toward the normal, unsupported side (**B**). Tilting the upper body toward the affected side shifts the center of gravity onto the stance side, thereby elevating the pelvis on the swing side (Duchenne's limp) (**C**). With bilateral loss of the small gluteals, the patient exhibits a typical waddling gait.

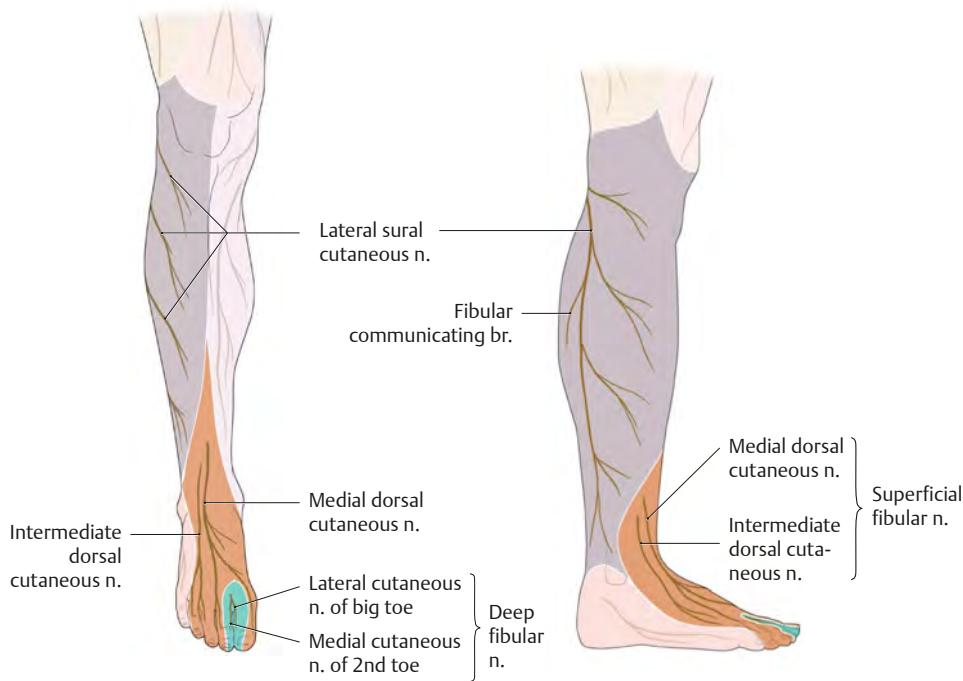


C Direct branches. Posterior view.

Nerves of the Sacral Plexus: Sciatic Nerve

The sciatic nerve gives off several direct muscular branches before dividing into the tibial and common fibular nerves proximal to the popliteal fossa.

Fig. 34.22 Common fibular nerve: Cutaneous distribution



A Right leg, anterior view.

B Right leg, lateral view.

Table 34.6 Common fibular nerve (L4–S2)		
Nerve	Innervated muscles	Sensory branches
Direct branches from sciatic n.	Bicep femoris (short head)	—
Superficial fibular n.	Fibularis brevis and longus	Medial dorsal cutaneous n. Intermediate dorsal cutaneous n.
Deep fibular n.	Tibialis anterior Extensors digitorum brevis and longus Extensors hallucis brevis and longus Fibularis tertius	Lateral cutaneous n. of big toe Medial cutaneous n. of 2nd toe

Fig. 34.23 Common fibular nerve
Right limb, lateral view.

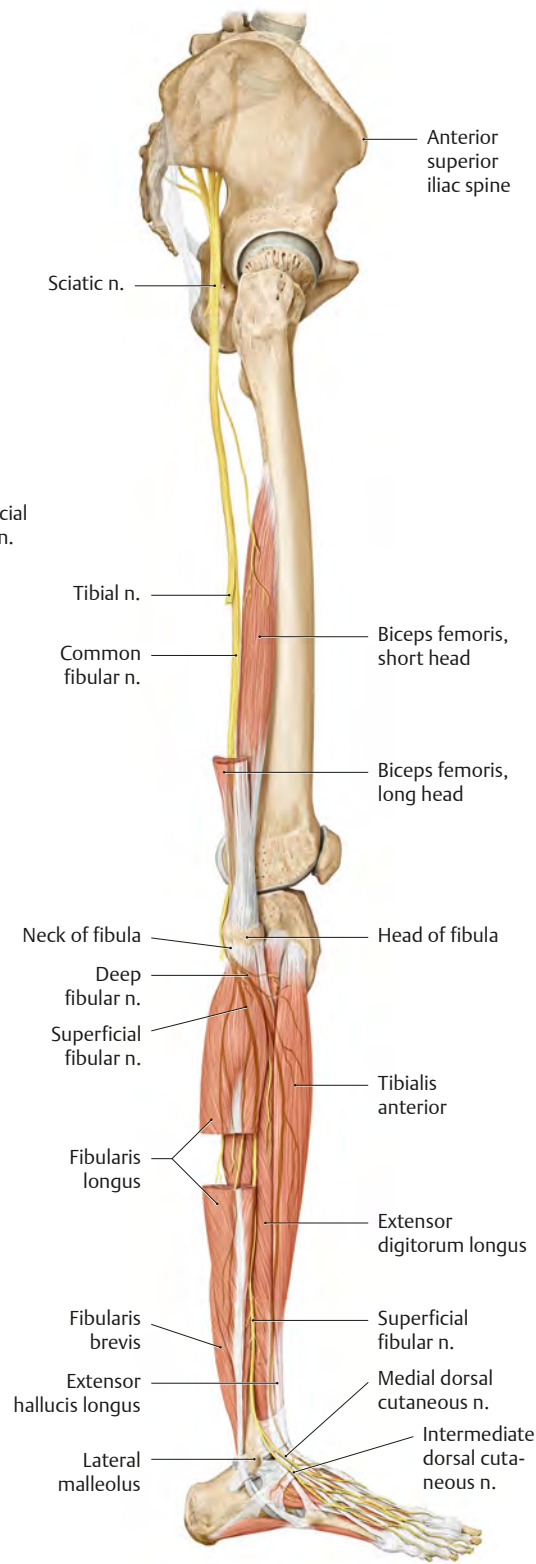
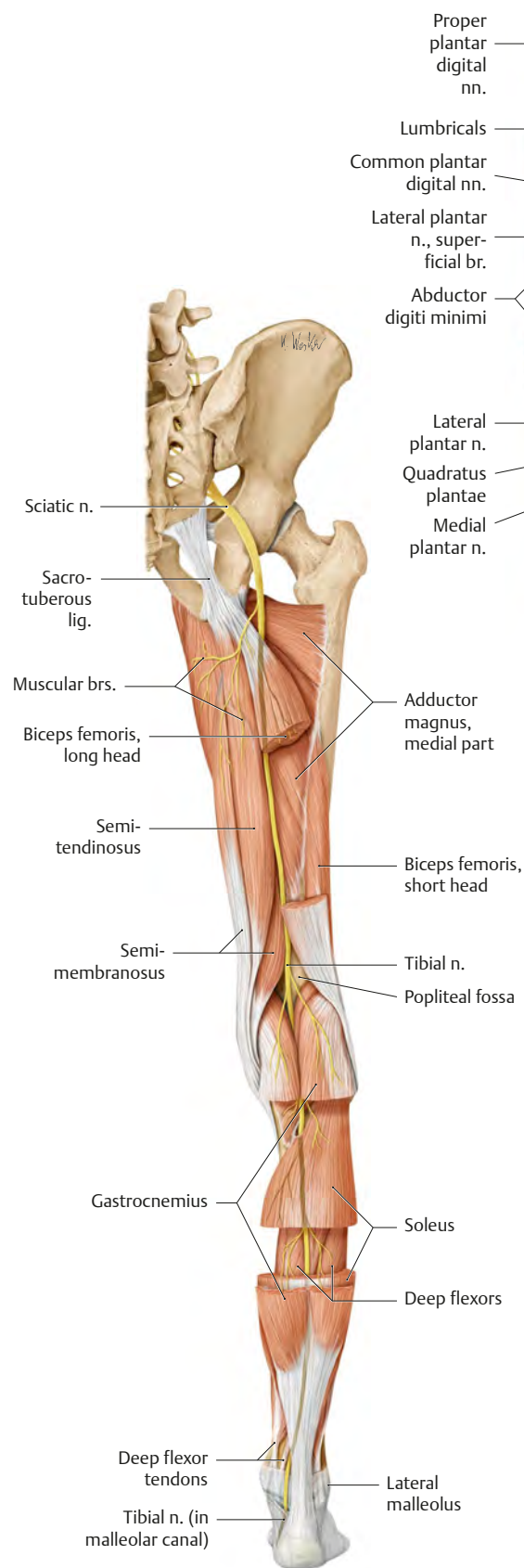
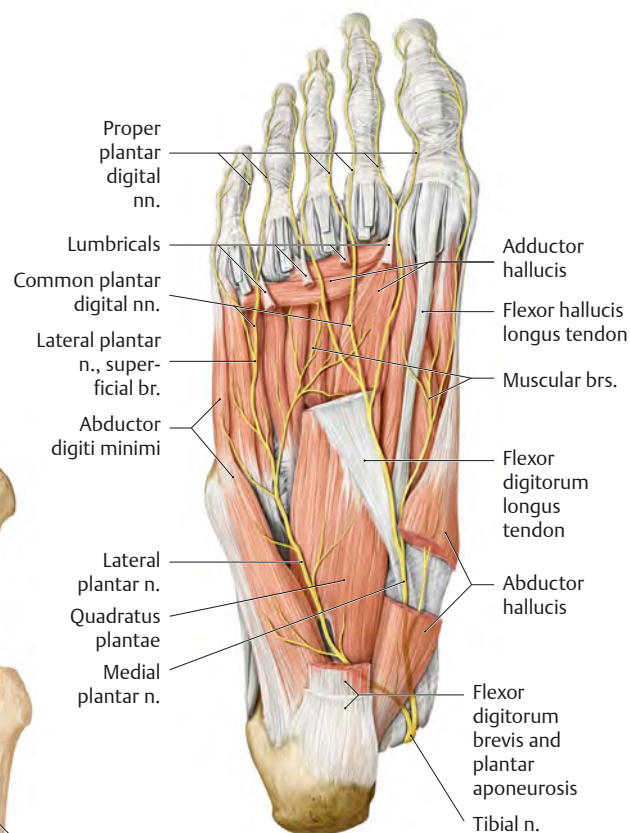


Fig. 34.24 Tibial nerve
Right limb.



A Posterior view.



B Right foot, plantar view.

Fig. 34.25 Tibial nerve: Cutaneous distribution
Right lower limb, posterior view.

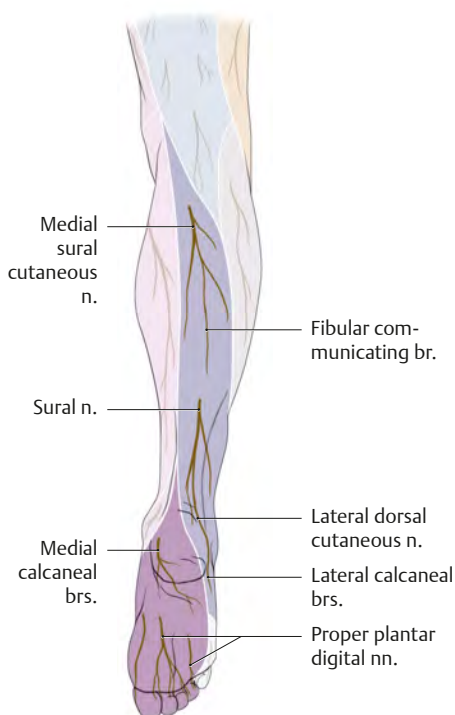


Table 34.7 Tibial nerve (L4–S3)		
Nerve	Innervated muscles	Sensory branches
Direct brs. from sciatic n.	Semitendinosus Semimembranosus Biceps femoris (long head) Adductor magnus (medial part)	—
Tibial n.	Triceps surae Plantaris Popliteus Tibialis posterior Flexor digitorum longus Flexor hallucis longus	Medial sural cutaneous n. Medial and lateral calcaneal brs. Lateral dorsal cutaneous n.
Medial plantar n.	Adductor hallucis Flexor digitorum brevis Flexor hallucis brevis (medial head) 1st lumbricals	Proper plantar digital nn.
Lateral plantar n.	Flexor hallucis brevis (lateral head) Quadratus plantae Abductor digiti minimi Flexor digiti minimi brevis Opponens digiti minimi 2nd to 4th lumbricals 1st to 3rd plantar interossei 1st to 4th dorsal interossei Adductor hallucis	Proper plantar digital nn.

Superficial Nerves & Veins of the Lower Limb

Fig. 34.26 Superficial cutaneous veins and nerves of right lower limb

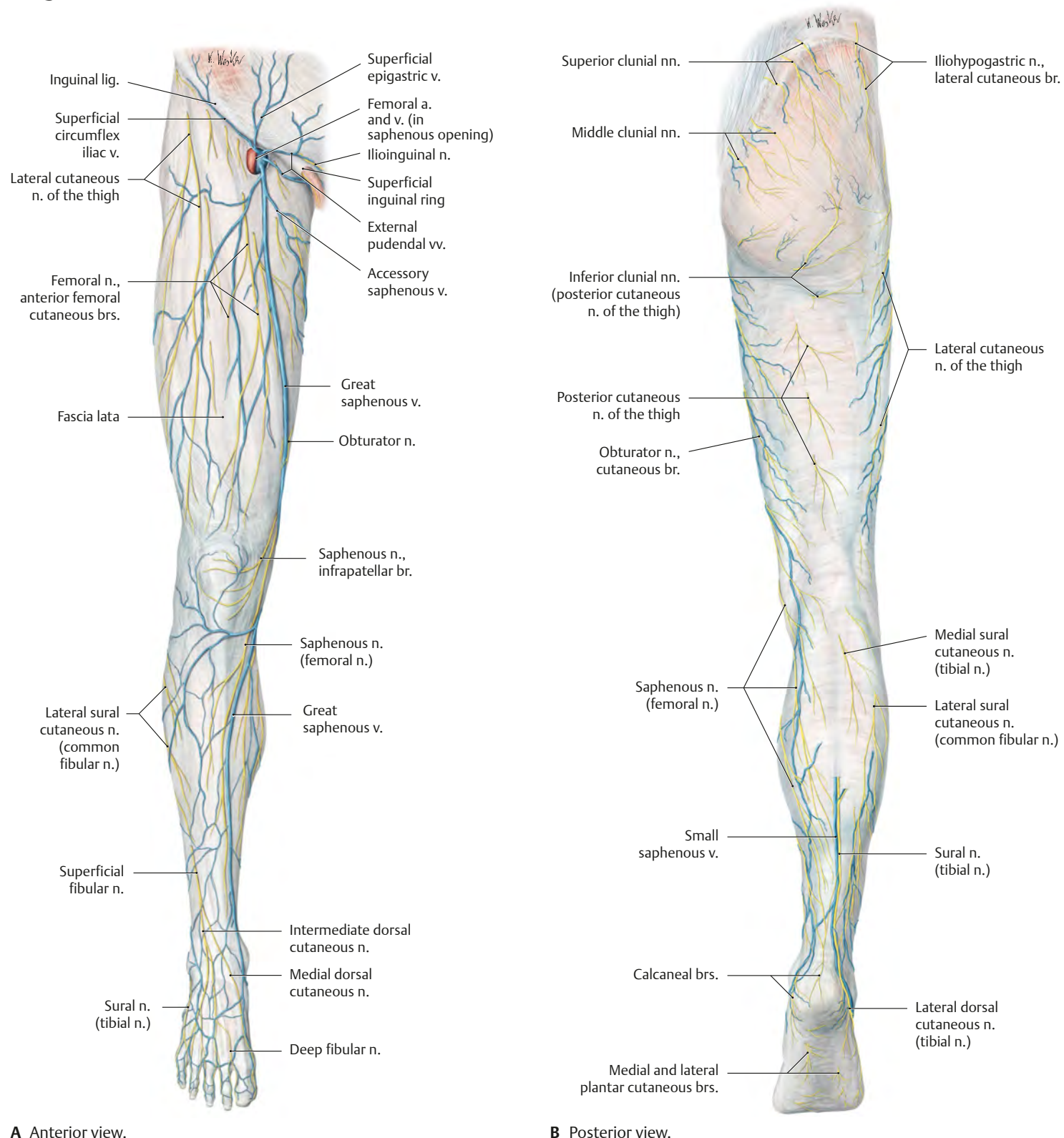
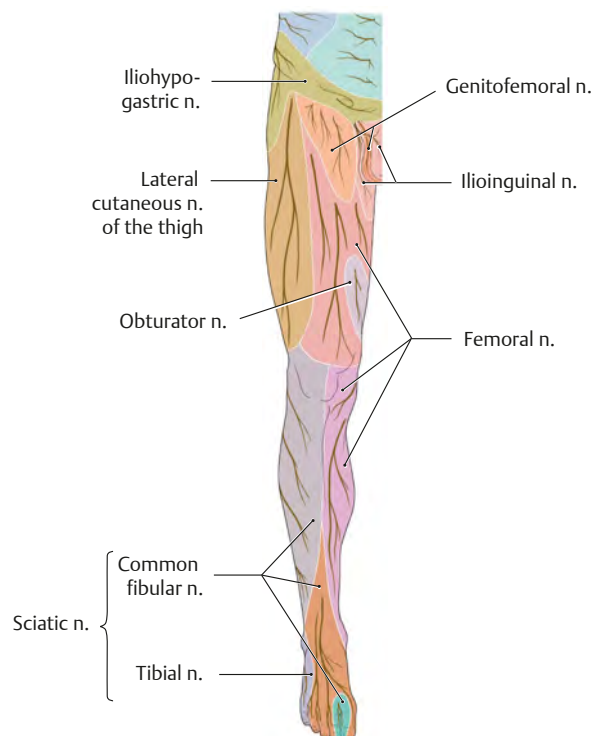
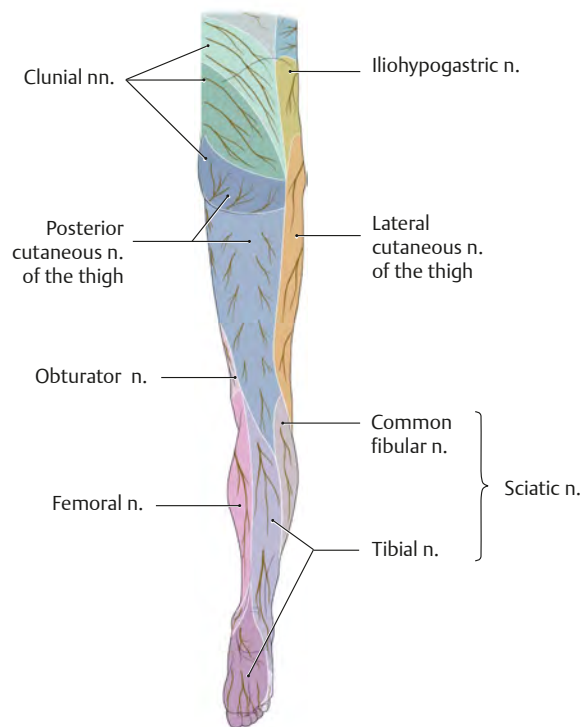


Fig. 34.27 Cutaneous innervation of the lower limb
Right lower limb.



A Anterior view.

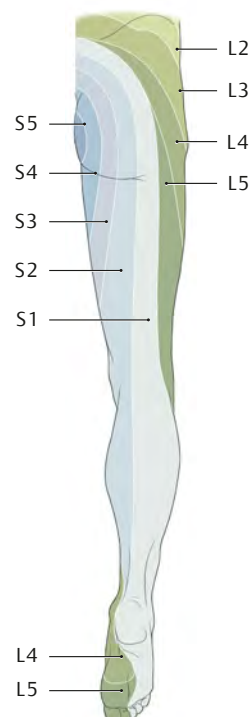


B Posterior view.

Fig. 34.28 Dermatomes of the lower limb
Right lower limb.



A Anterior view.



B Posterior view.

Topography of the Inguinal Region

Fig. 34.29 Superficial veins and lymph nodes

Right male inguinal region, anterior view. *Removed:* Cribriform fascia over the saphenous opening.

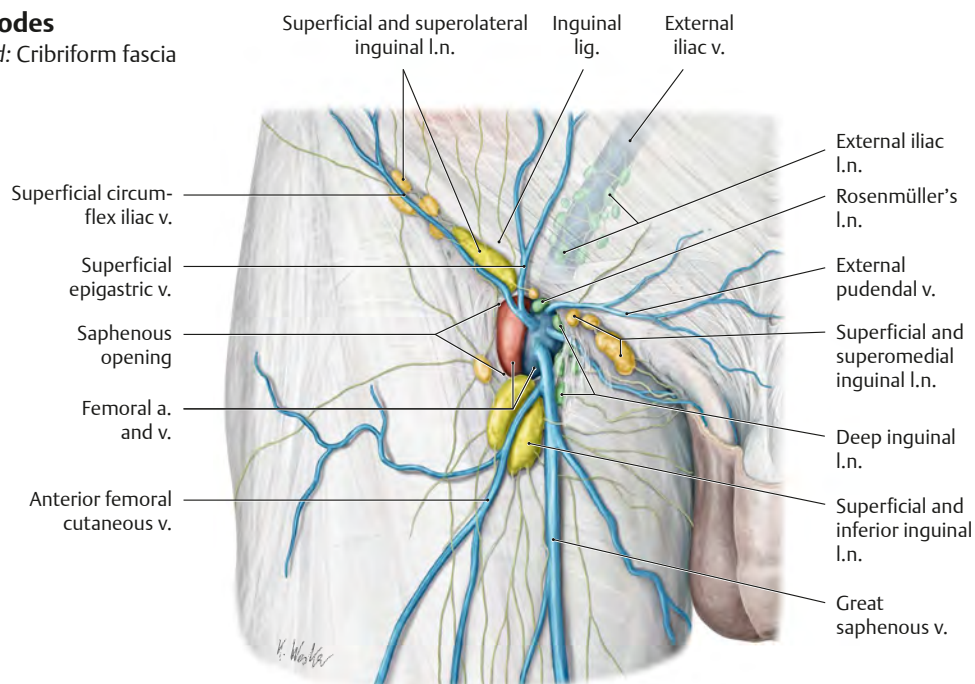
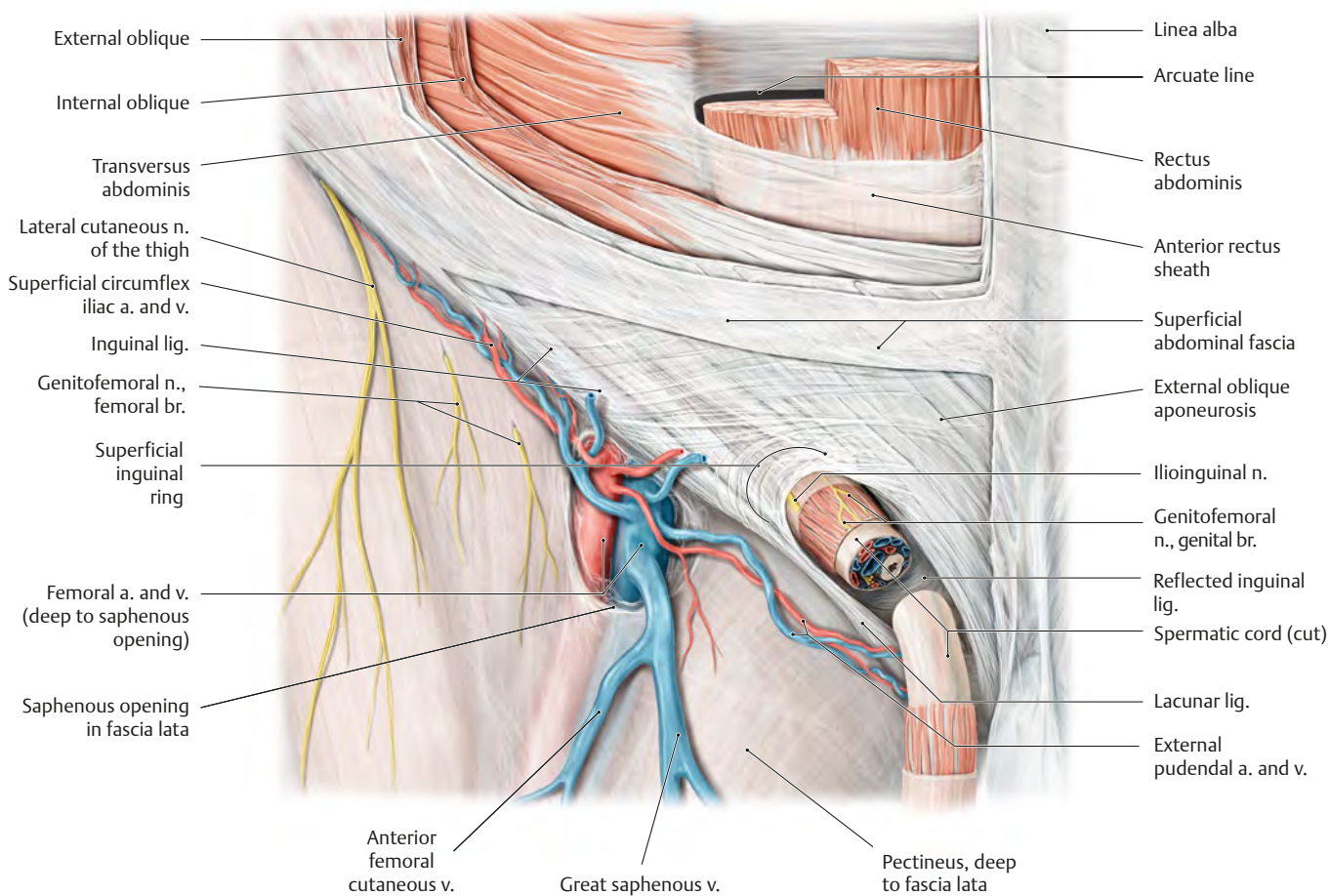


Fig. 34.30 Inguinal region

Right male inguinal region, anterior view.



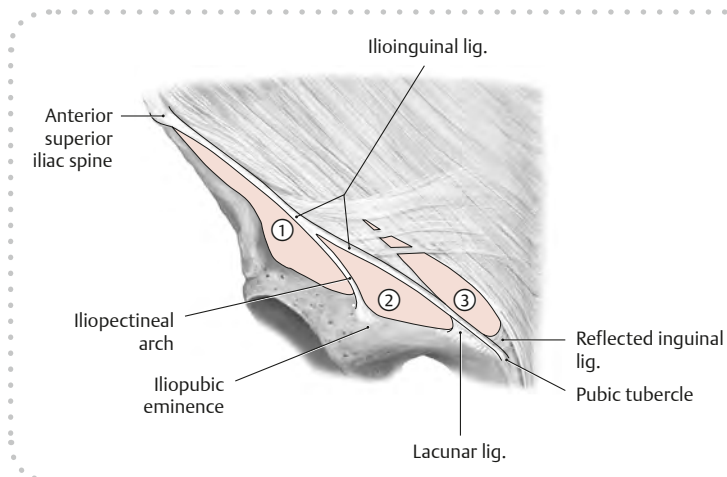
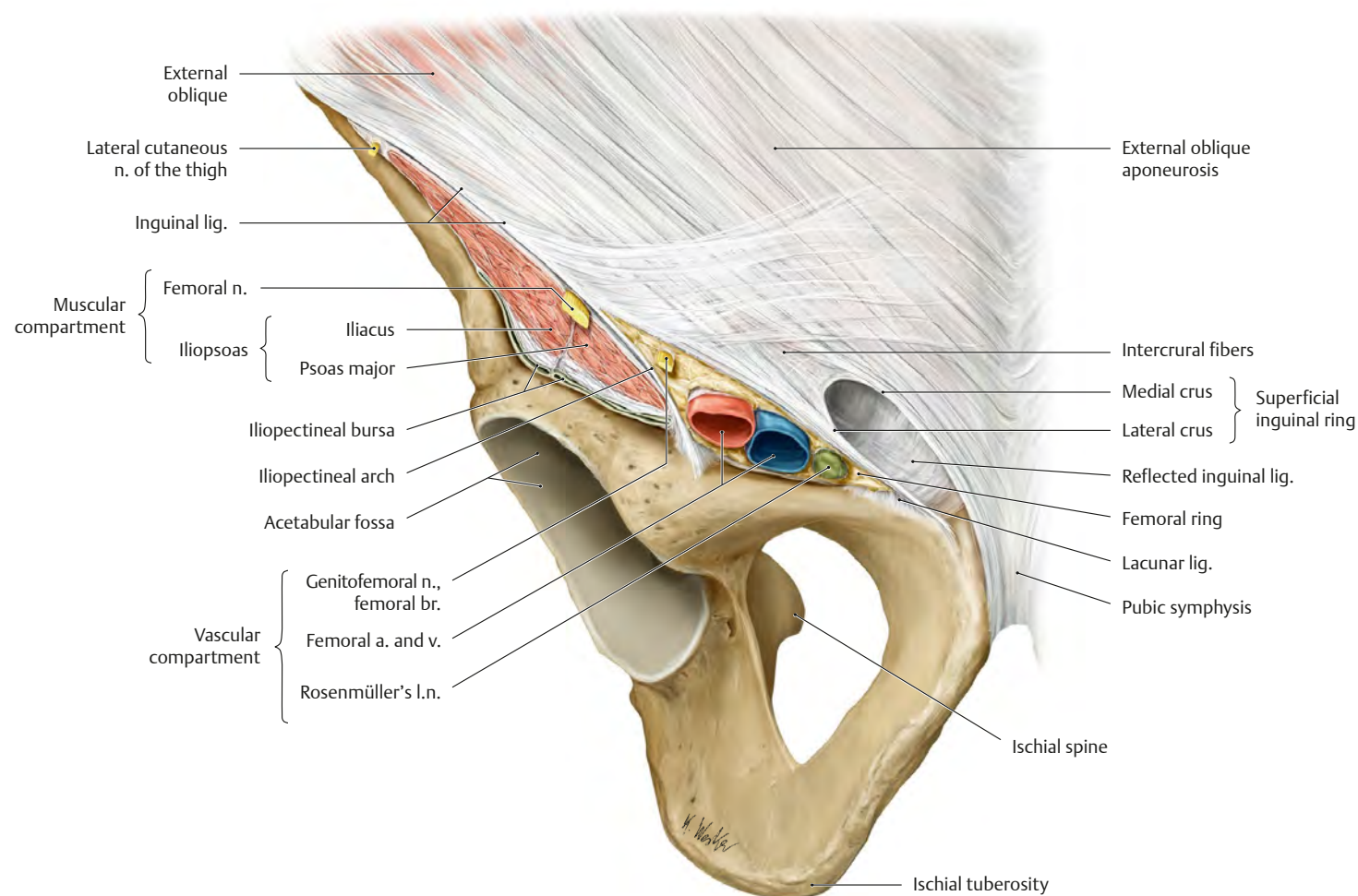


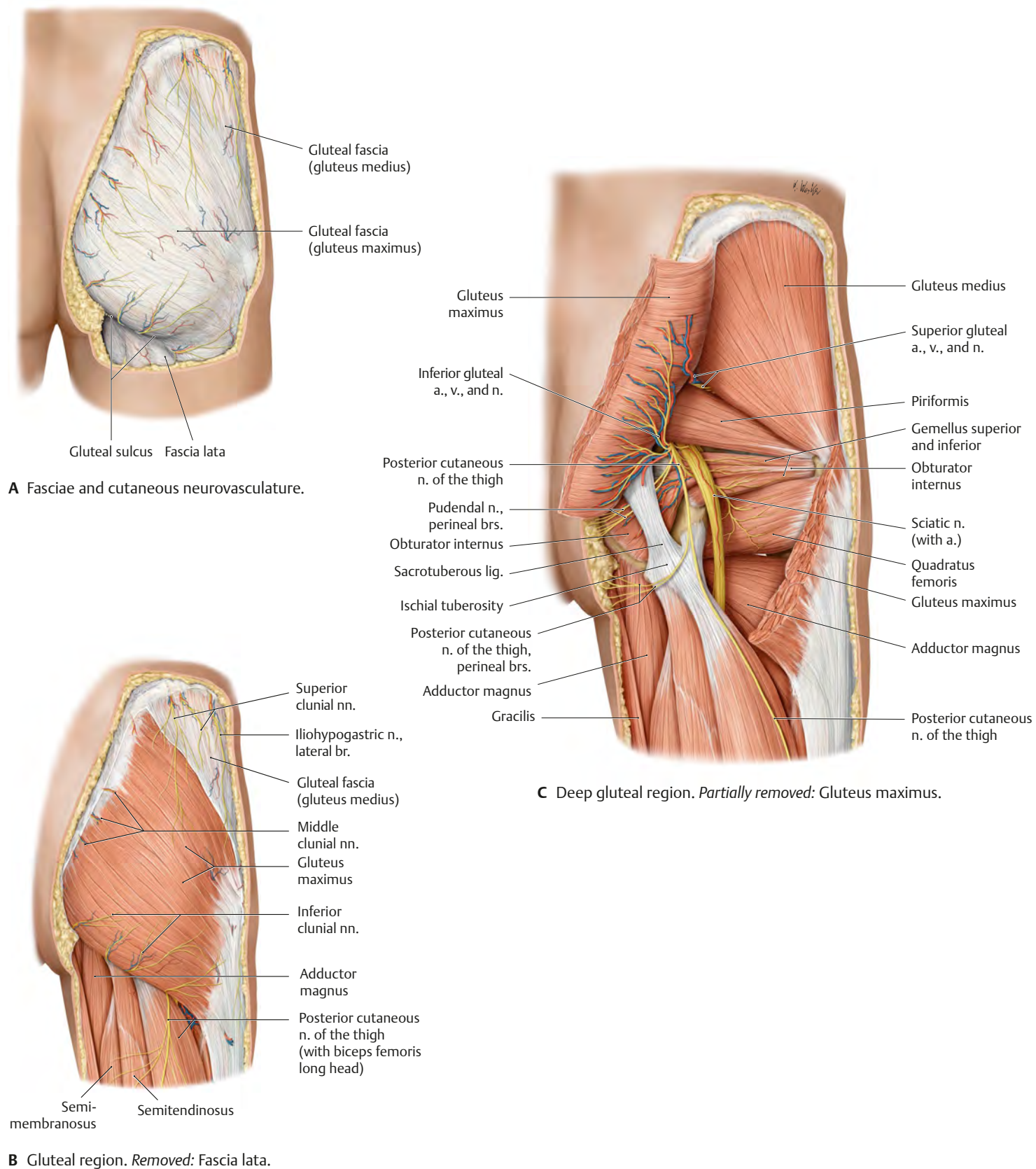
Table 34.8 Structures in the inguinal region		
Region	Boundaries	Contents
Retro-inguinal space		
① Muscular compartment	Anterior superior iliac spine Inguinal lig. Iliopectineal arch	Femoral n. Lateral cutaneous n. of the thigh Iliacus Psoas major
② Vascular compartment	Inguinal lig. Iliopectineal arch Lacunar lig.	Femoral a. and v. Genitofemoral n., femoral br. Rosenmüller's lymph node
Inguinal canal		
③ Superficial inguinal ring	Medial crus Lateral crus Reflected inguinal lig.	Ilioinguinal n. Genitofemoral n., genital br. Spermatic cord

Fig. 34.31 Retro-inguinal space:
Muscular and vascular compartments
Right inguinal region, anterior view.



Topography of the Gluteal Region

Fig. 34.32 Gluteal region
Right gluteal region, posterior view.



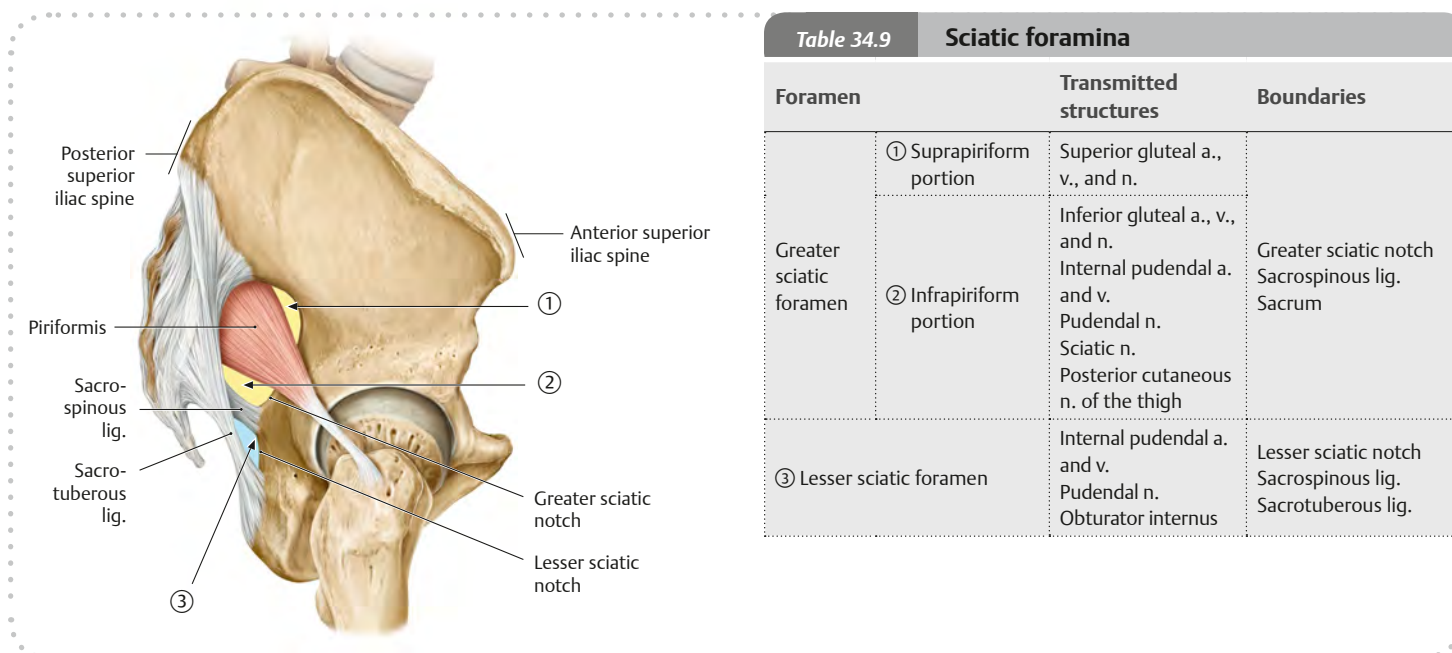
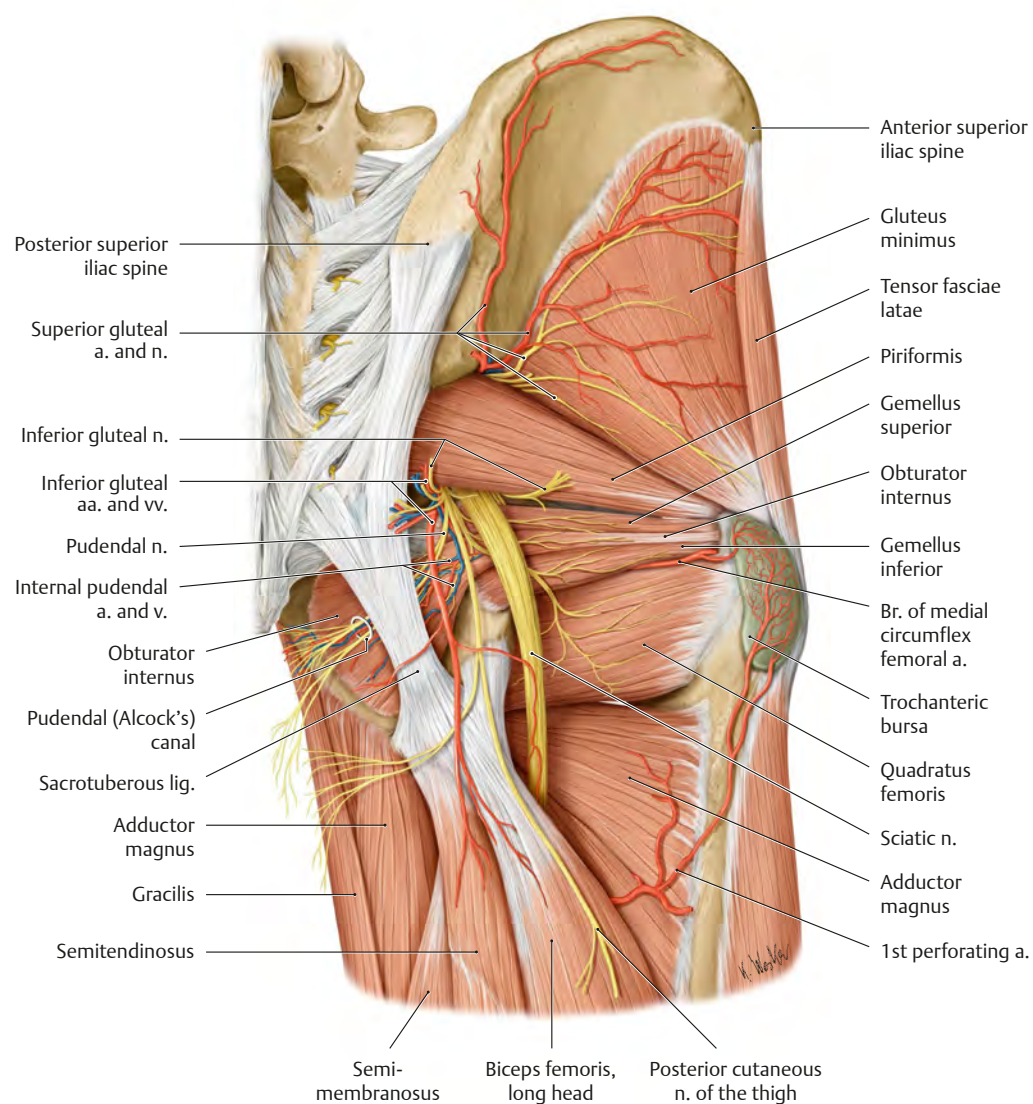


Fig. 34.33 Gluteal region and ischioanal fossa

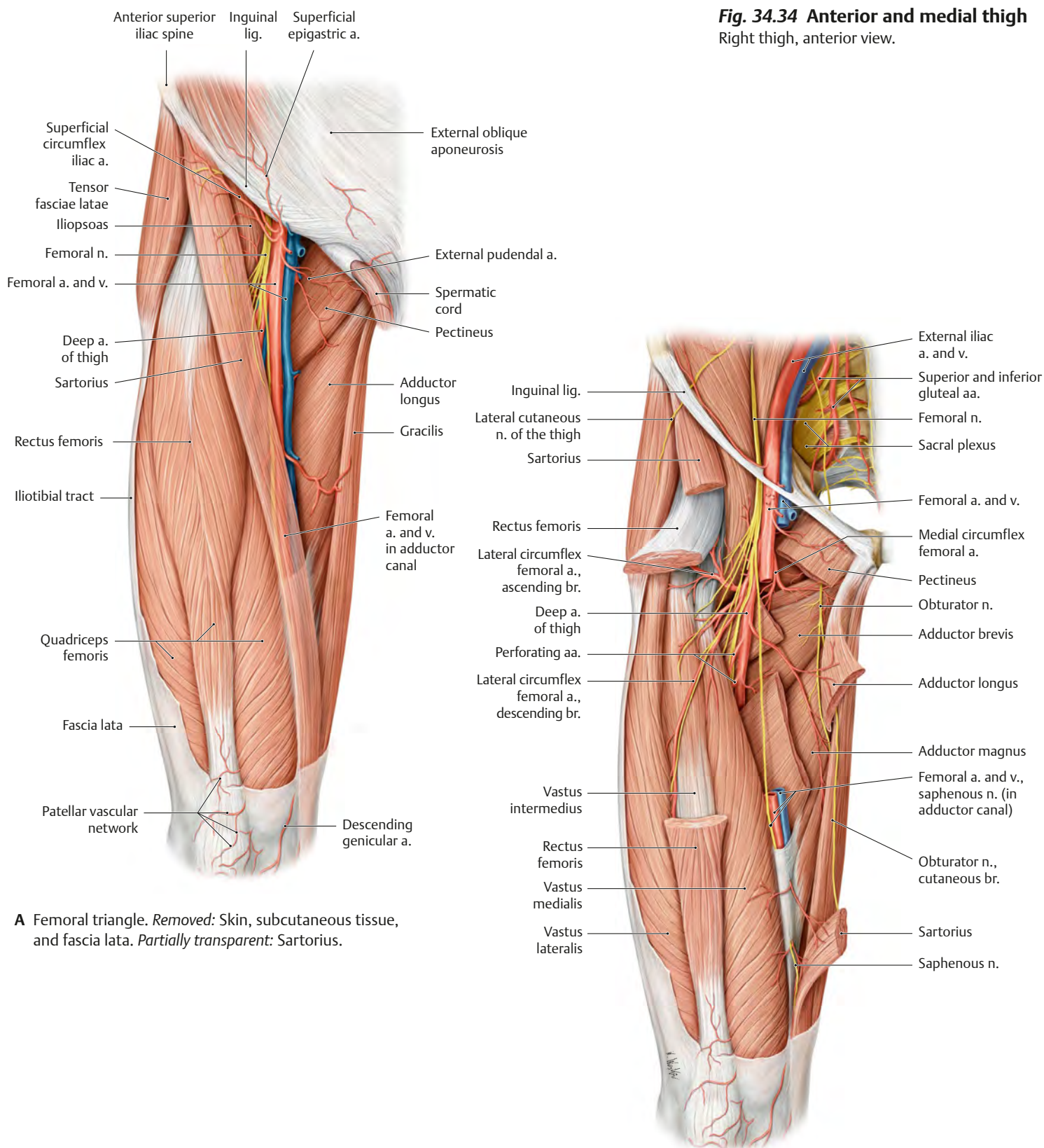
Right gluteal region, posterior view.

Removed: Gluteus maximus and medius.



Topography of the Anterior, Medial & Posterior Thigh

Fig. 34.34 Anterior and medial thigh
Right thigh, anterior view.



A Femoral triangle. *Removed:* Skin, subcutaneous tissue, and fascia lata. *Partially transparent:* Sartorius.

B Neurovasculature of the anterior thigh. *Removed:* Anterior abdominal wall. *Partially removed:* Sartorius, rectus femoris, adductor longus, and pectineus.

Fig. 34.35 Posterior thigh
Right thigh, posterior view.

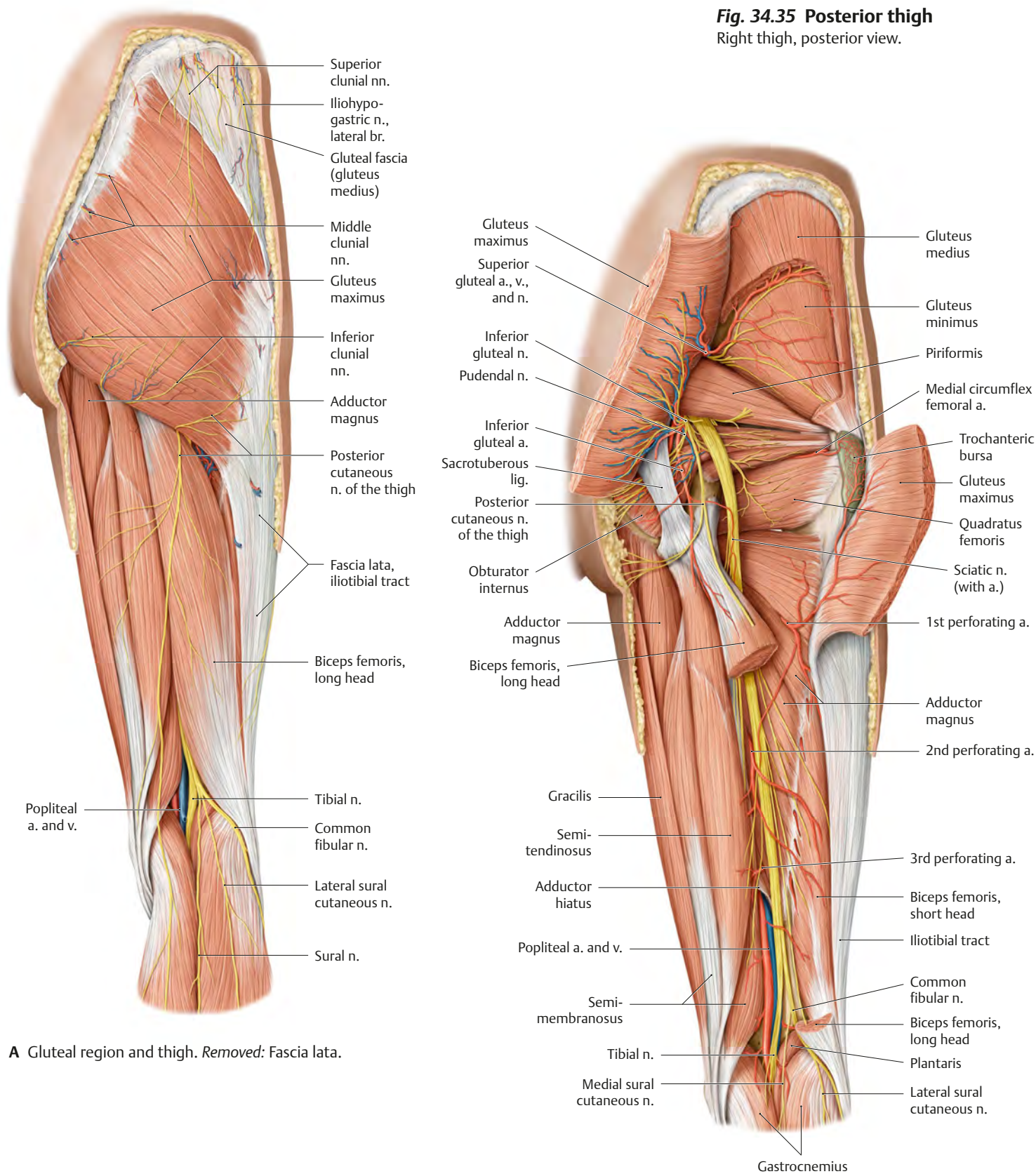
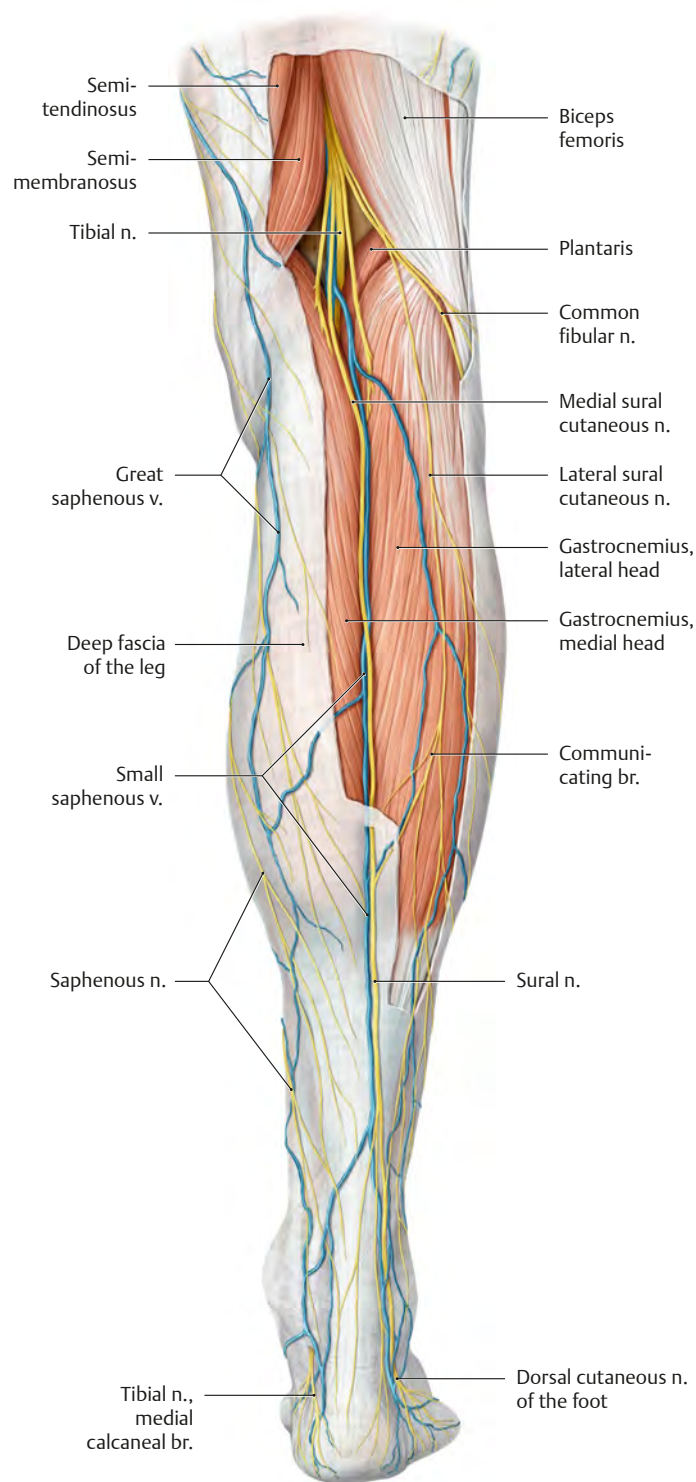
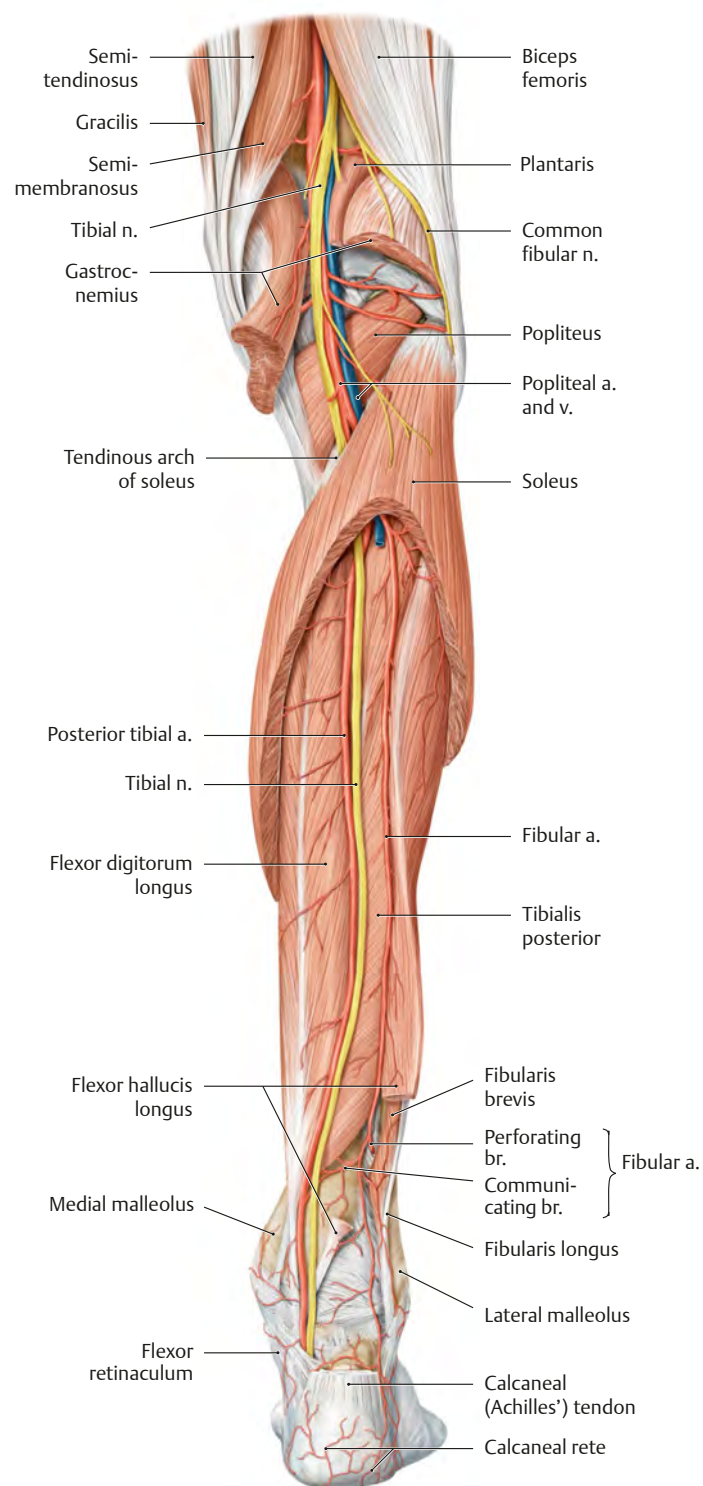


Fig. 34.36 Posterior compartment of leg
Right leg, posterior view.



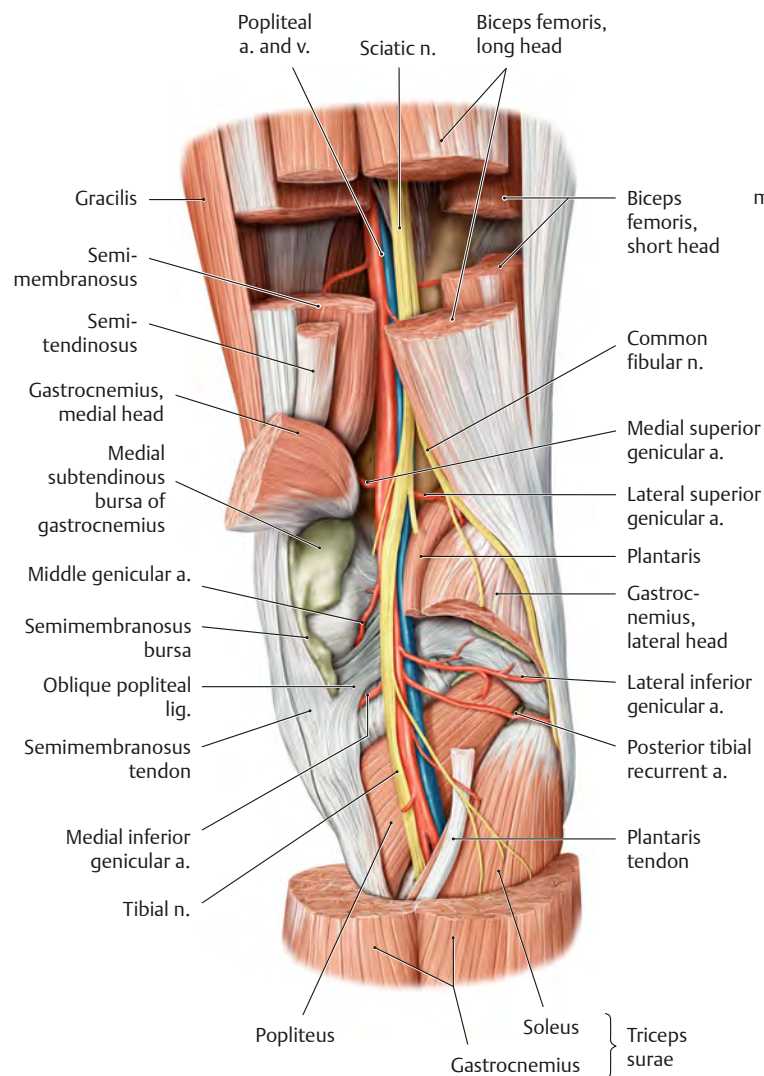
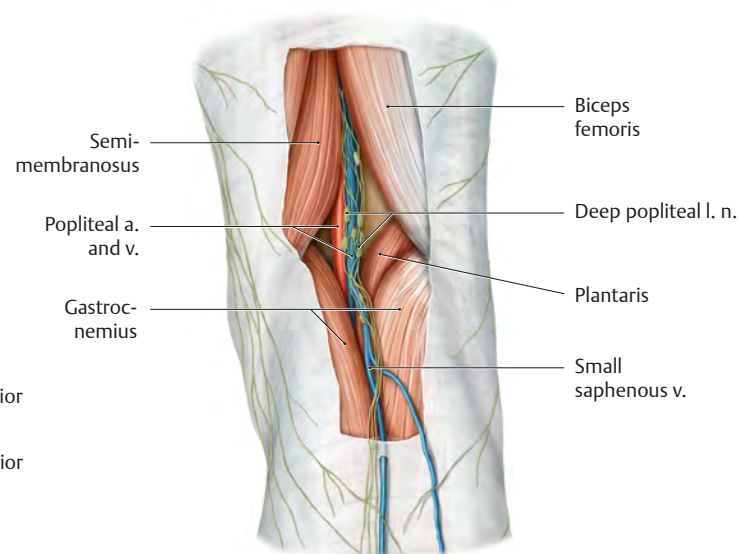
A Superficial neurovascular structures.



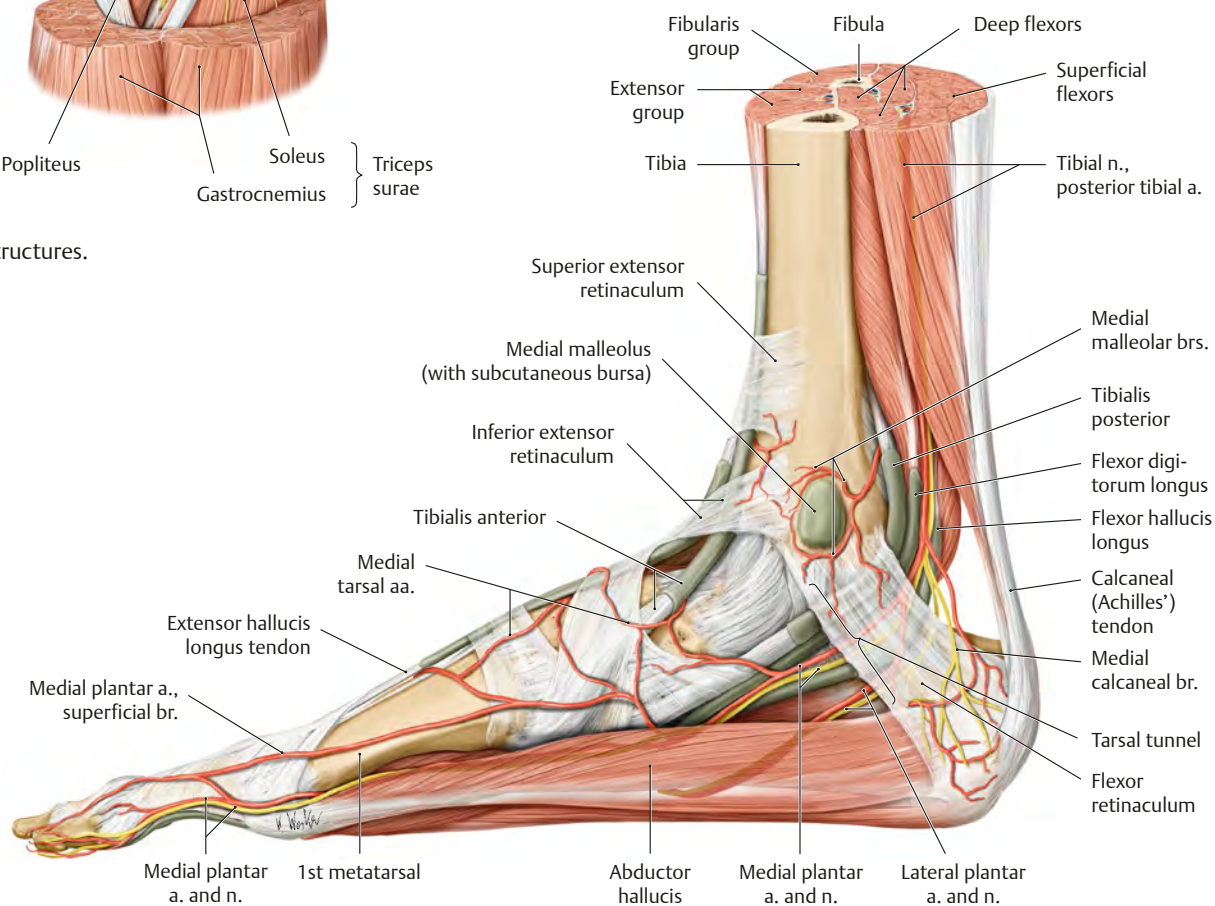
B Deep neurovascular structures. *Removed:* Gastrocnemius. *Windowed:* Soleus.

Fig. 34.37 Popliteal region

Right leg, posterior view.

**A Deep neurovascular structures.****B Deep lymph nodes.****Fig. 34.38 Ankle region**

Right ankle, medial view.



Topography of the Lateral & Anterior Compartments of the Leg & Dorsum of the Foot

Fig. 34.39 Neurovasculature of the lateral compartment of the leg
Right limb. *Removed:* Origins of the fibularis longus and extensor digitorum longus.

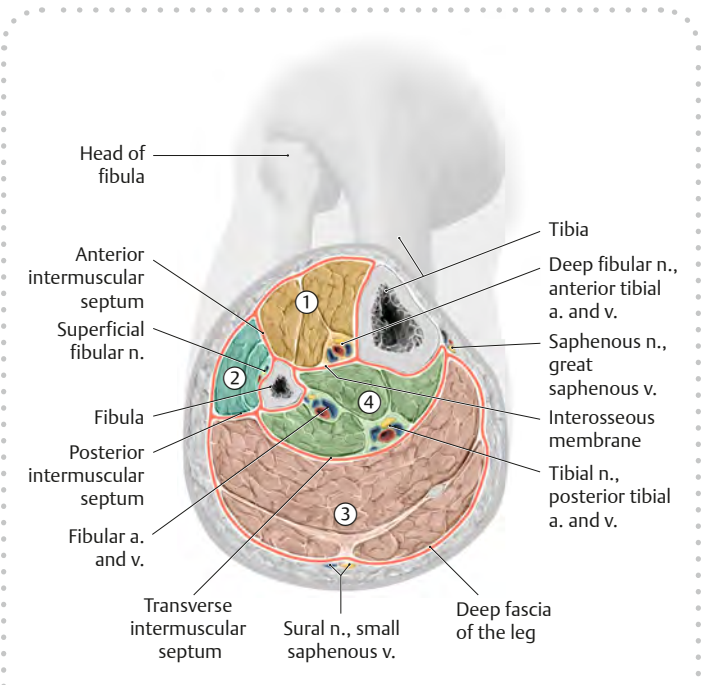
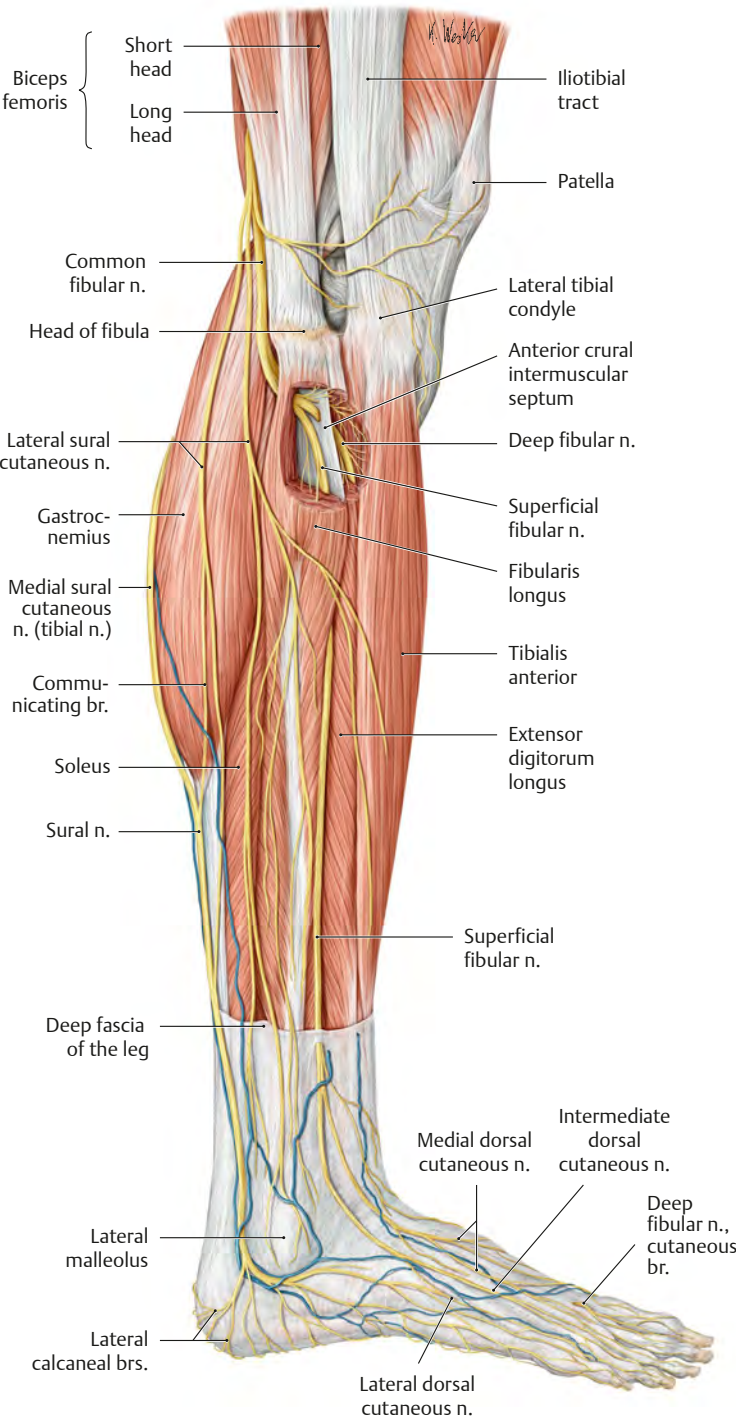


Table 34.10 Compartments of the leg		
Compartment	Muscular contents	Neurovascular contents
① Anterior compartment	Tibialis anterior	Deep fibular n. Anterior tibial a. and v.
	Extensor digitorum longus	
	Extensor hallucis longus	
	Fibularis tertius	
② Lateral compartment	Fibularis longus	Superficial fibular n.
	Fibularis brevis	
Posterior compartment	Triceps surae (gastrocnemius and soleus)	—
	Plantaris	
	Tibialis posterior	Tibial n. Posterior tibial a. and v. Fibular a. and v.
	Flexor digitorum longus	
	Flexor hallucis longus	



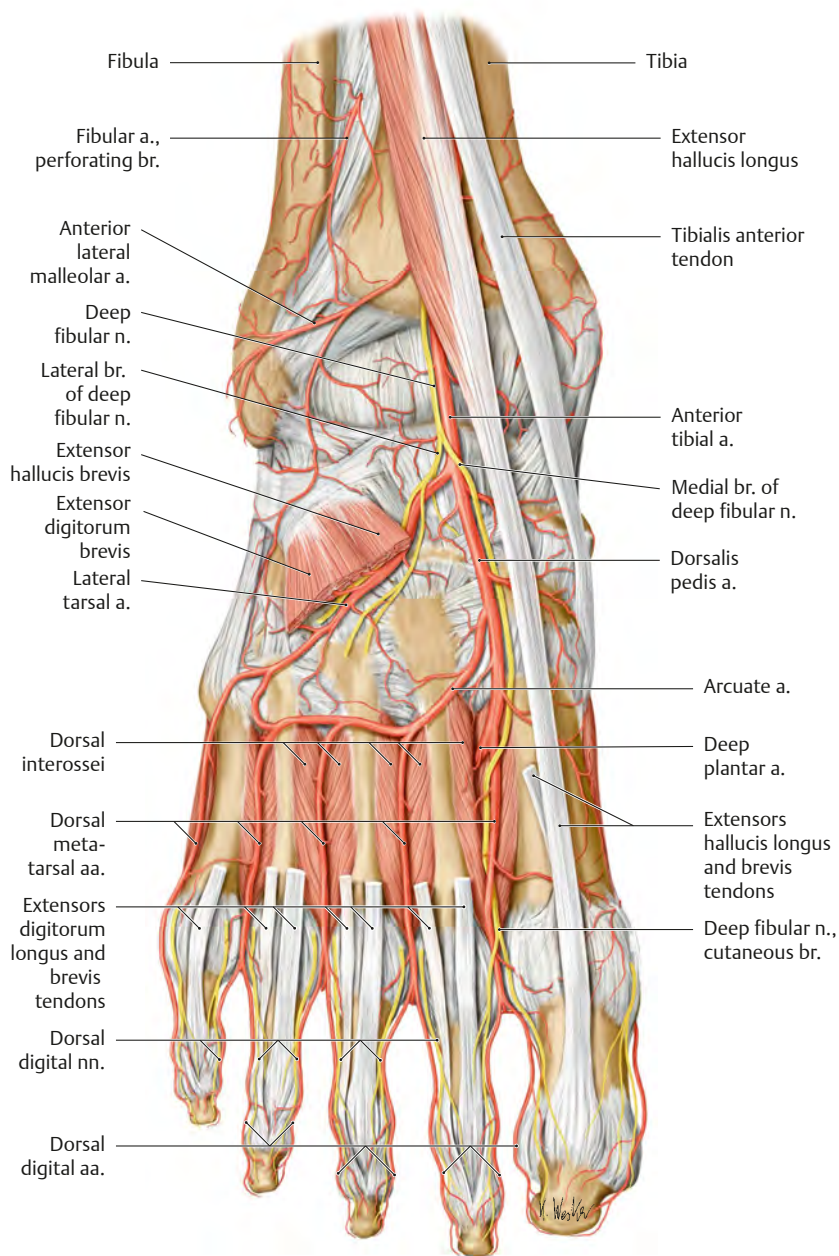
Clinical box 34.5

Compartment syndrome

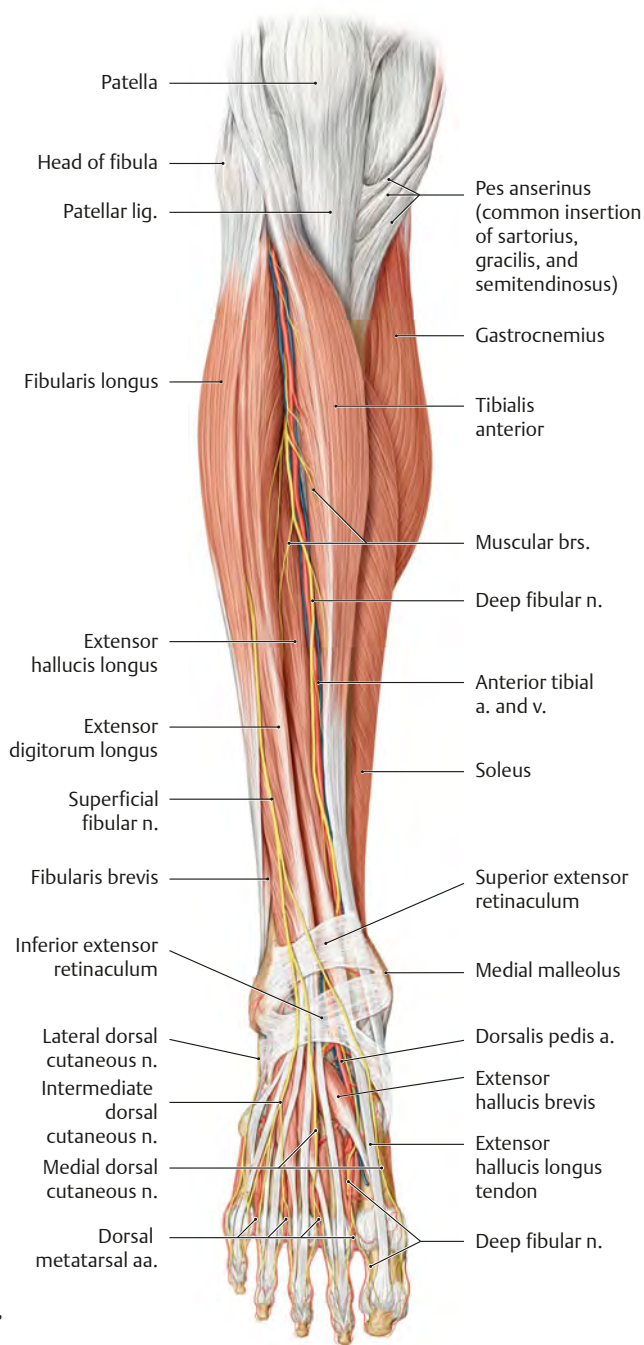
Muscle edema or hematoma can lead to a rise in tissue fluid pressure in the compartments of the leg. Subsequent compression of neurovascular structures due to this increased pressure may cause ischemia and irreversible muscle and nerve damage. Patients with *anterior* compartment syndrome, the most common form, suffer excruciating pain and cannot dorsiflex the toes. Emergency incision of the fascia of the leg may be performed to relieve compression.

Fig. 34.40 Neurovasculature of the anterior compartment of the leg and foot

Right limb with foot in plantar flexion.

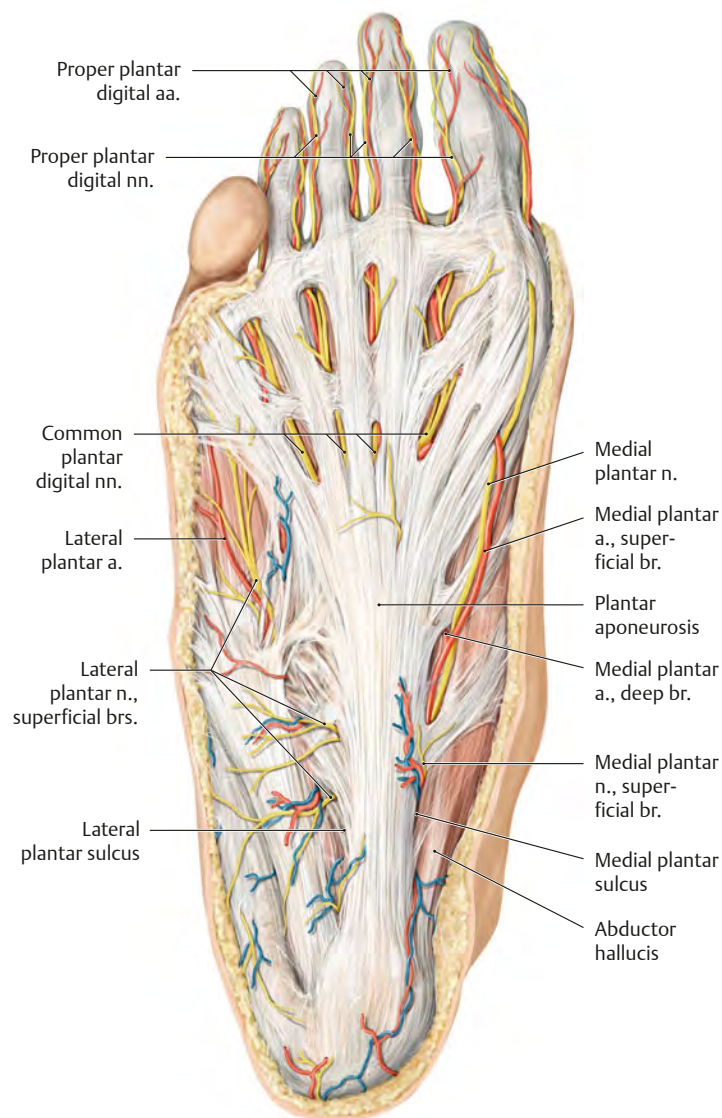


A Neurovasculature of the dorsum of the foot.



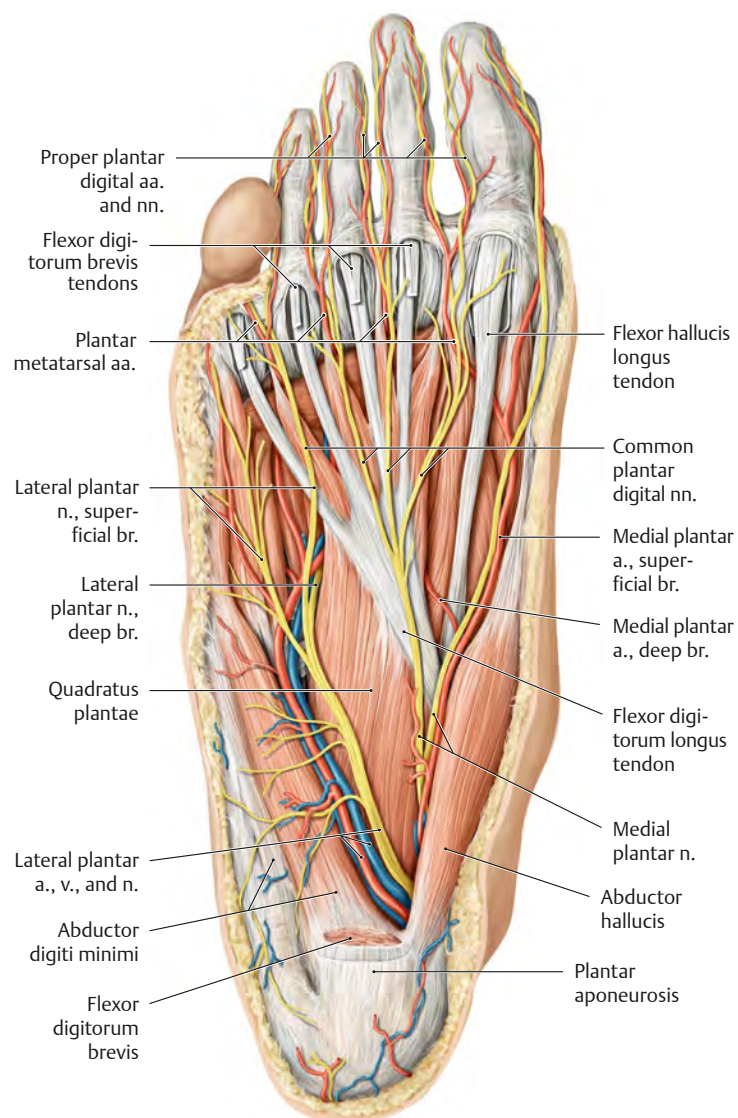
B Neurovasculature of the leg. *Removed:* Skin, subcutaneous tissue, and fasciae. *Retracted:* Tibialis anterior and extensor hallucis longus.

Topography of the Sole of the Foot



A Superficial layer. *Removed:* Skin, subcutaneous tissue, and fascia.

Fig. 34.41 Neurovasculature of the sole of the foot
Right foot, plantar view.



B Middle layer. *Removed:* Plantar aponeurosis and flexor digitorum brevis.

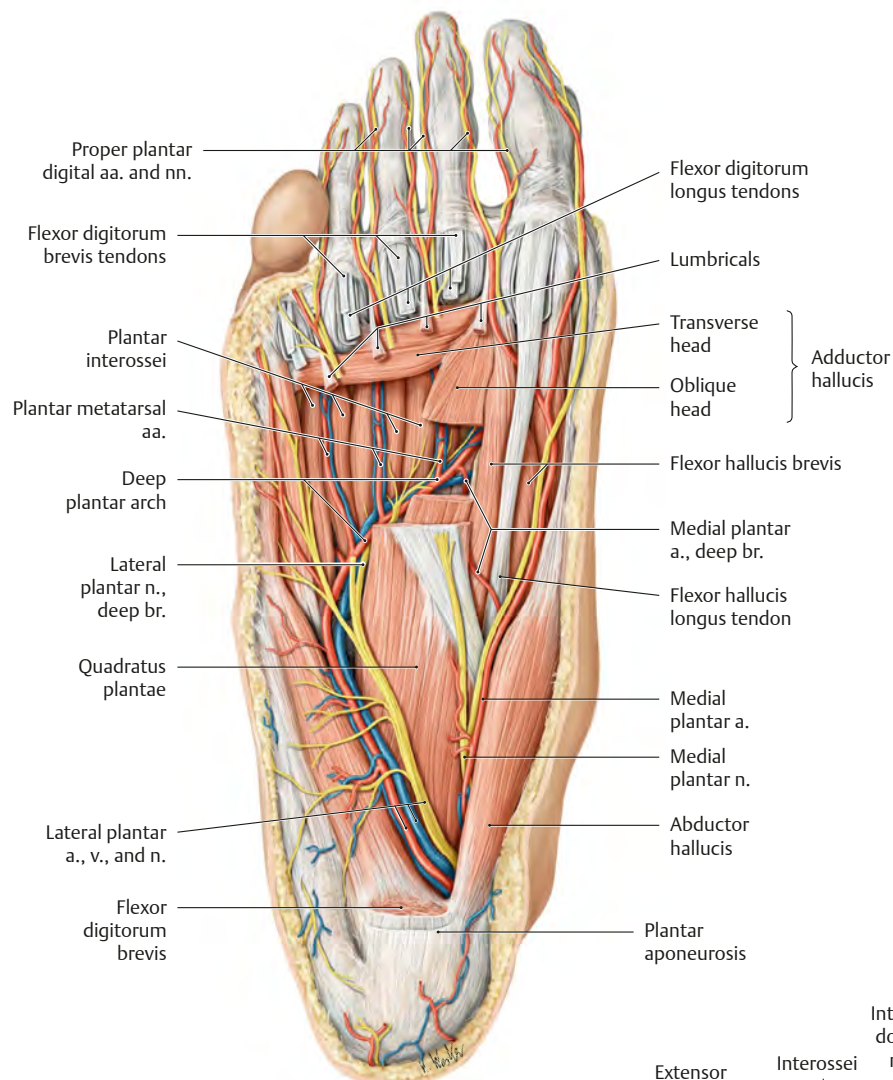
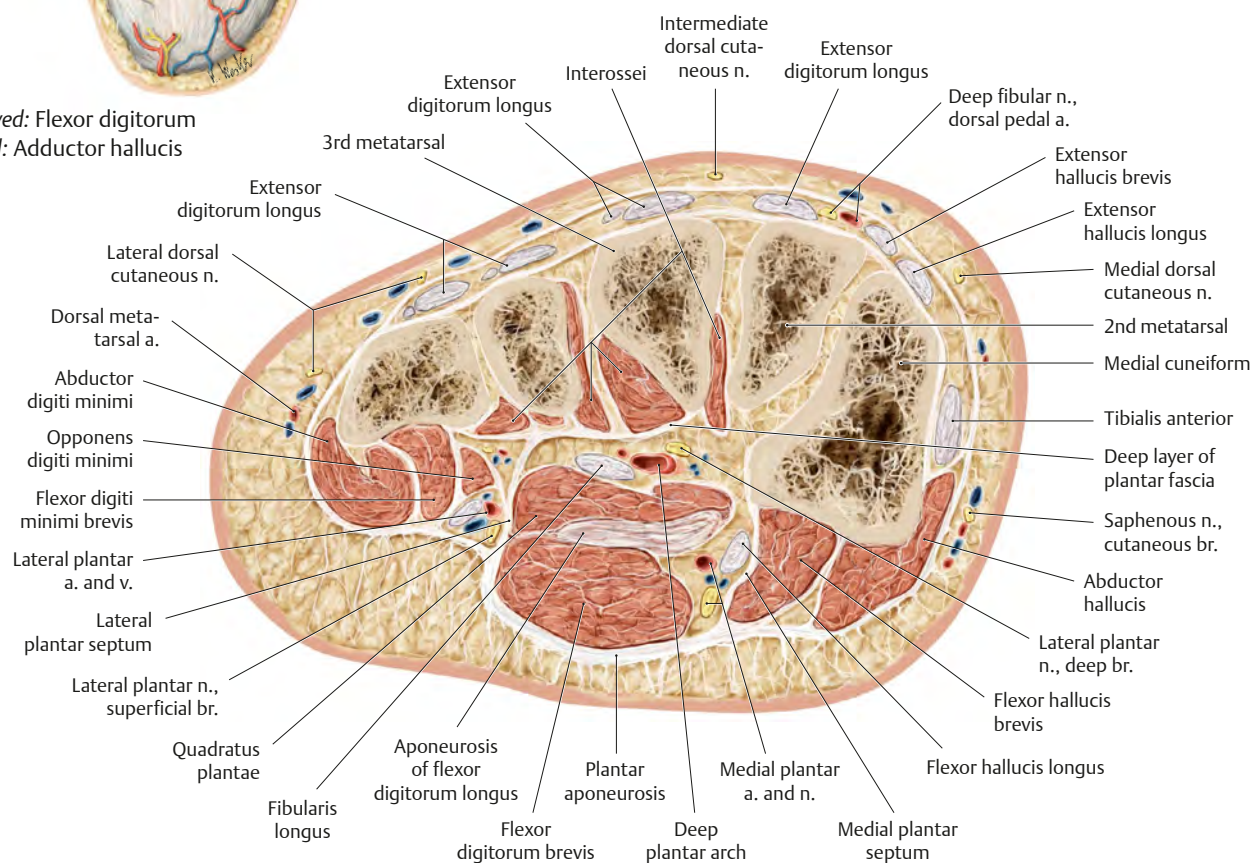


Fig. 34.42 Neurovasculature of the foot: Cross section
Coronal section, distal view.

C Deep layer. Removed: Flexor digitorum longus. Windowed: Adductor hallucis (oblique head).



35 Sectional & Radiographic Anatomy

Sectional Anatomy of the Lower Limb

Fig. 35.1 Windowed dissection of the thigh and leg
Right limb, posterior view.

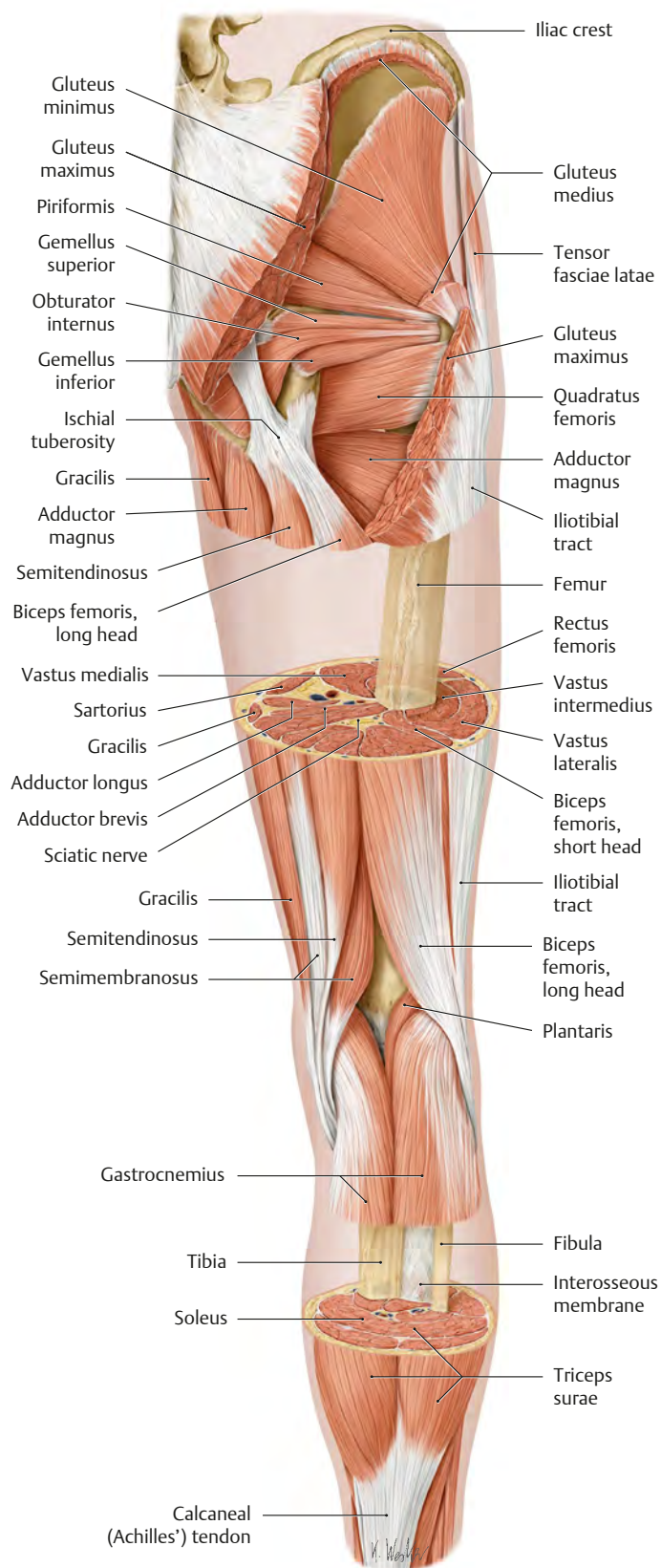
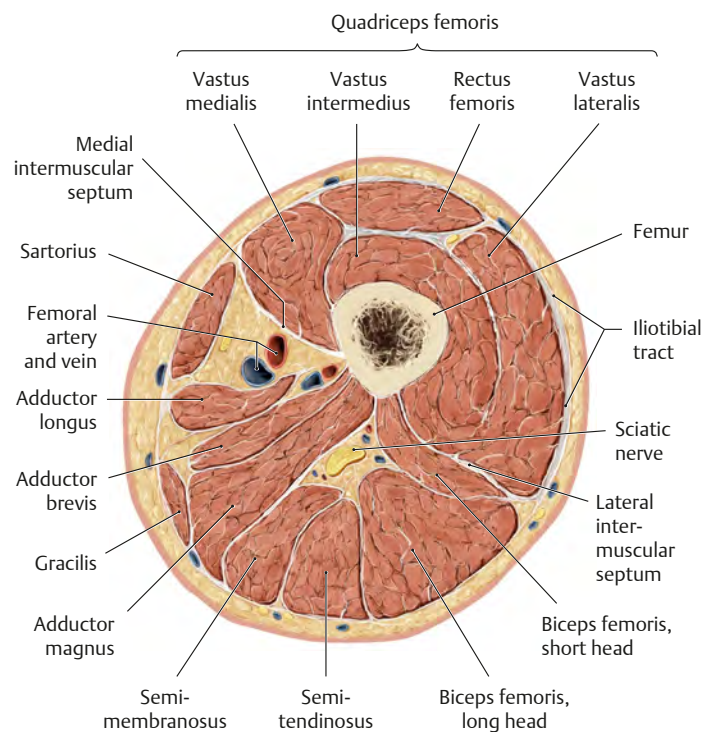
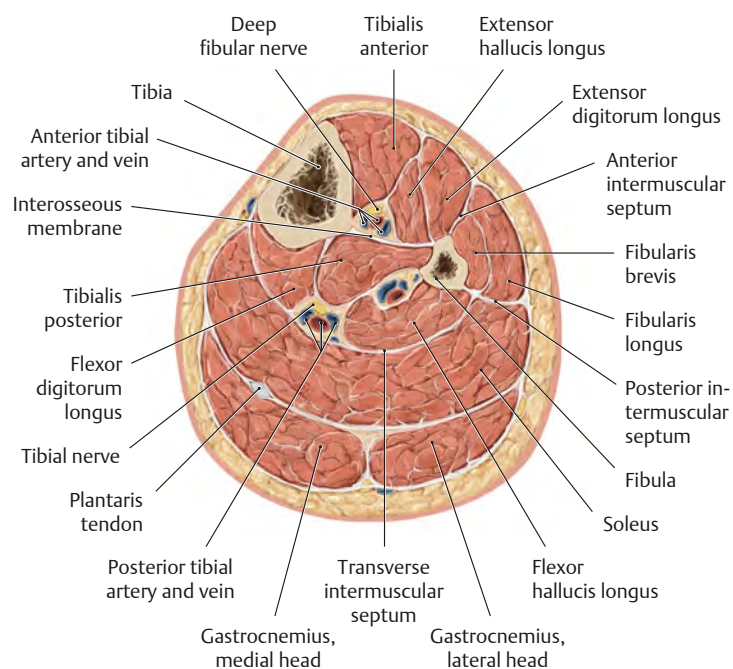


Fig. 35.2 Cross-section through the thigh and leg
Right limb, proximal view.



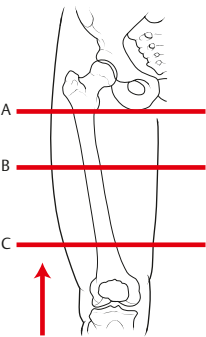
A Thigh (plane of upper section in Fig. 35.1A)



B Leg (plane of lower section in Fig. 35.1B)

Radiographic Anatomy of the Lower Limb (I)

Fig. 35.3 MRI of the thigh
Transverse section, distal
(inferior) view.



A Proximal thigh. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

B Mid-thigh. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

C Distal thigh. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)

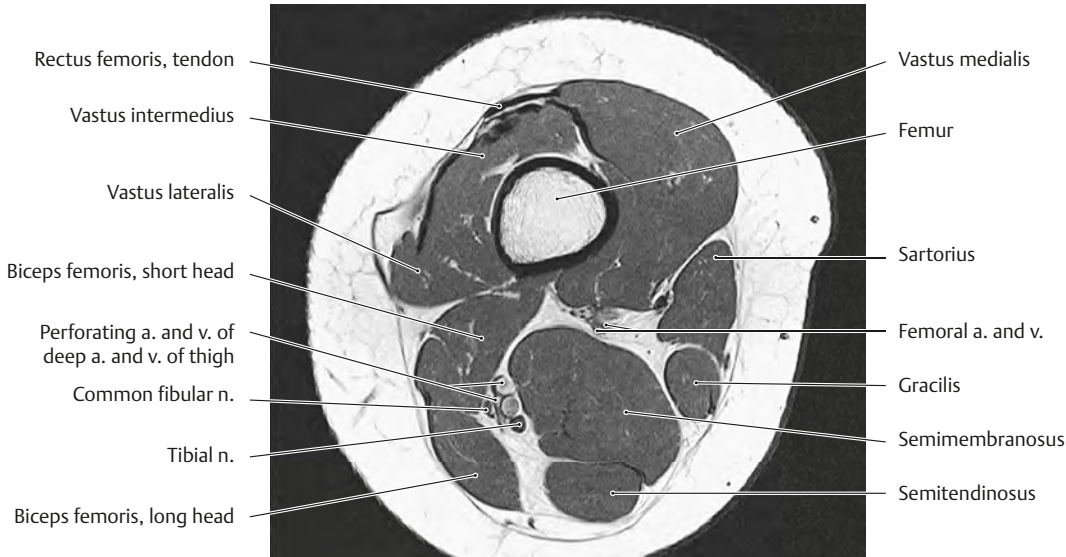
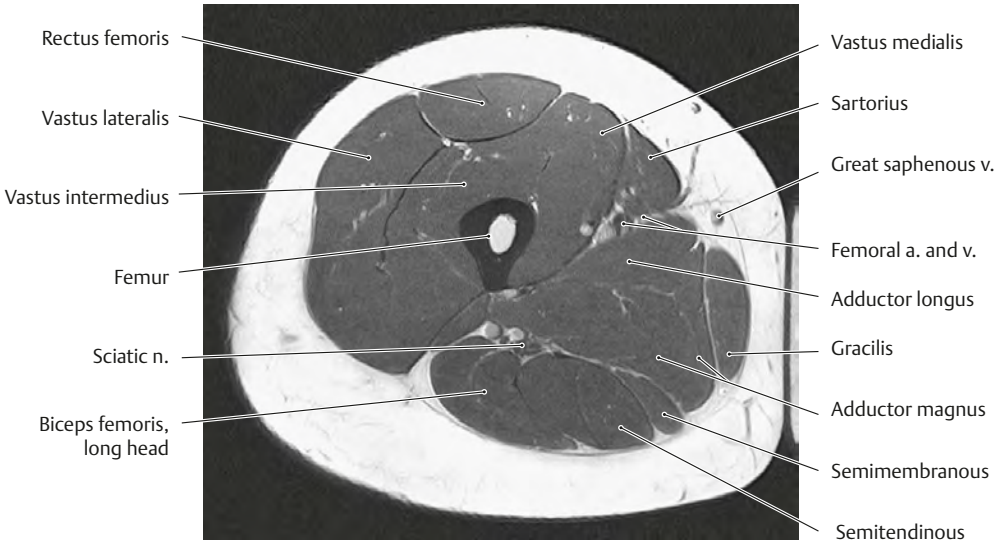
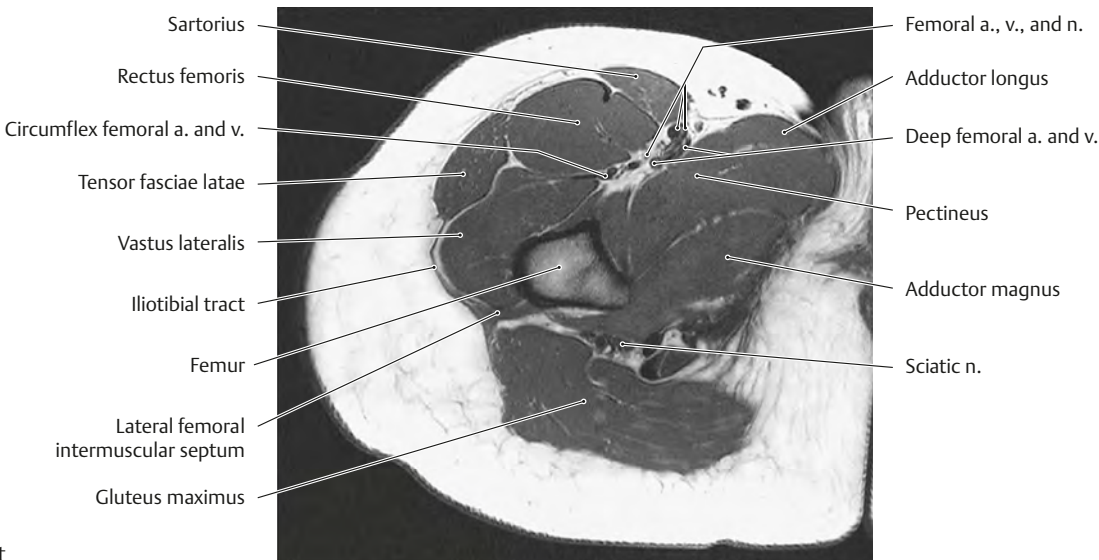
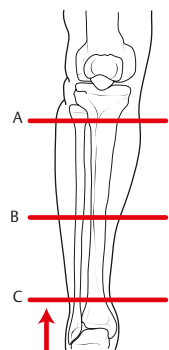
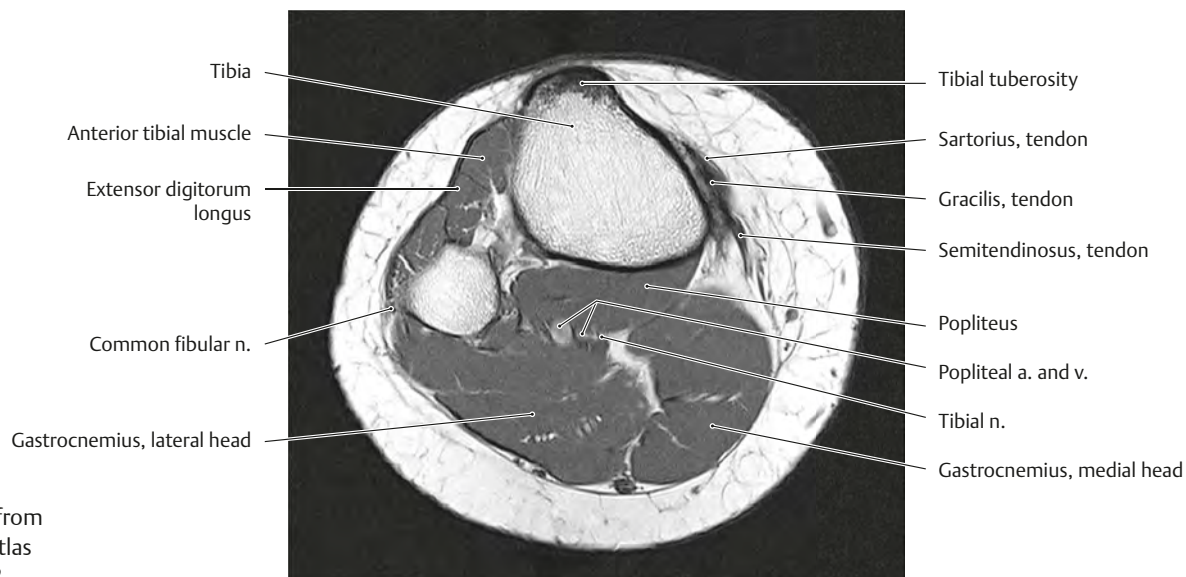


Fig. 35.4 MRI of the leg

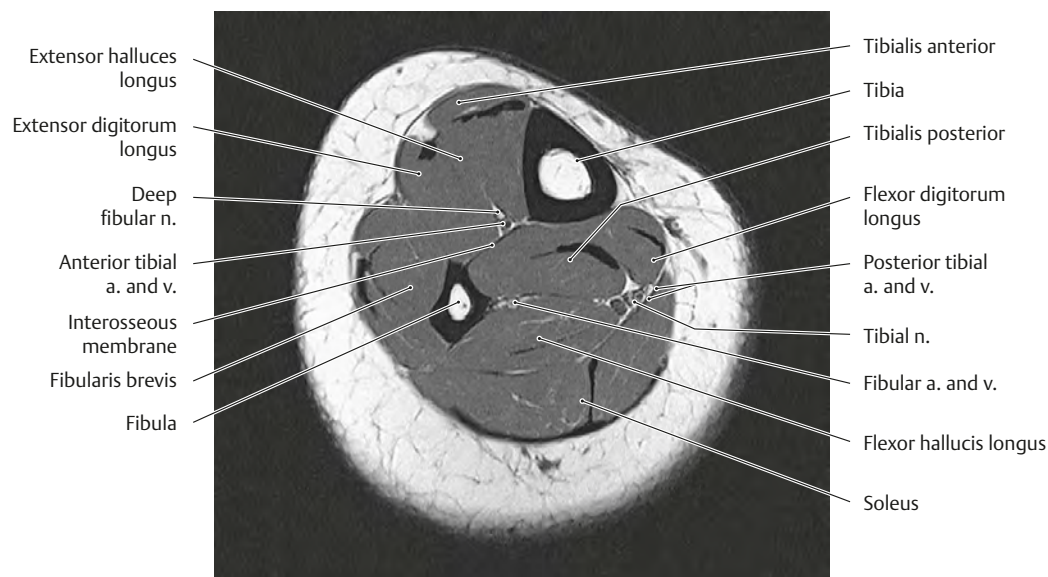
Transverse section, distal (inferior) view.



A Proximal leg. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)



B Mid-leg. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)



C Distal leg. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 2, 4th ed. New York, NY: Thieme; 2014.)



Fig. 35.5 Radiograph of the right hip joint
Anteroposterior view.

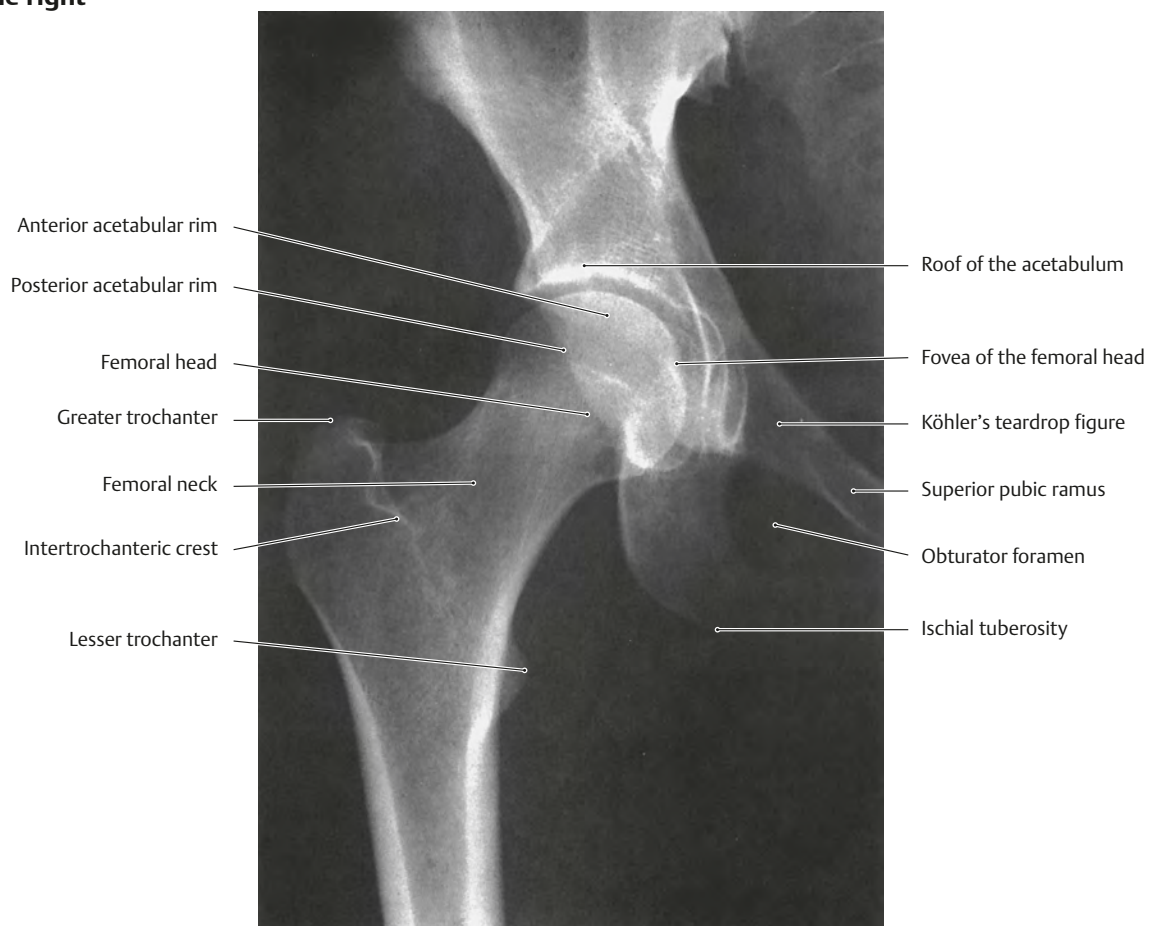


Fig. 35.6 Radiograph of right hip joint with limb abducted laterally (Lauenstein view)

(Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

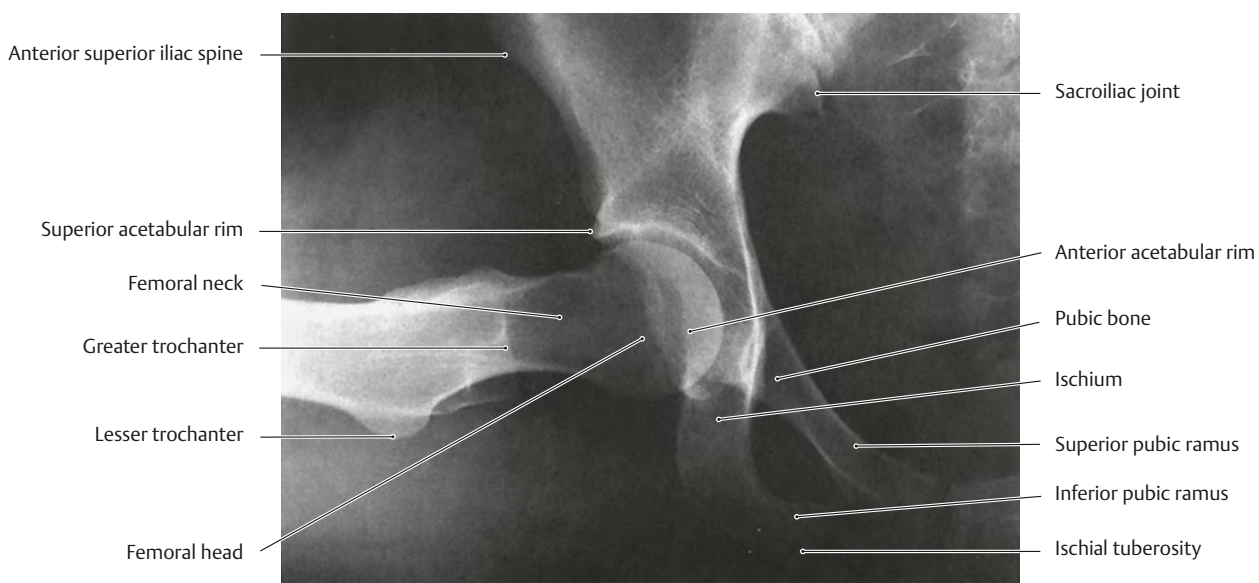
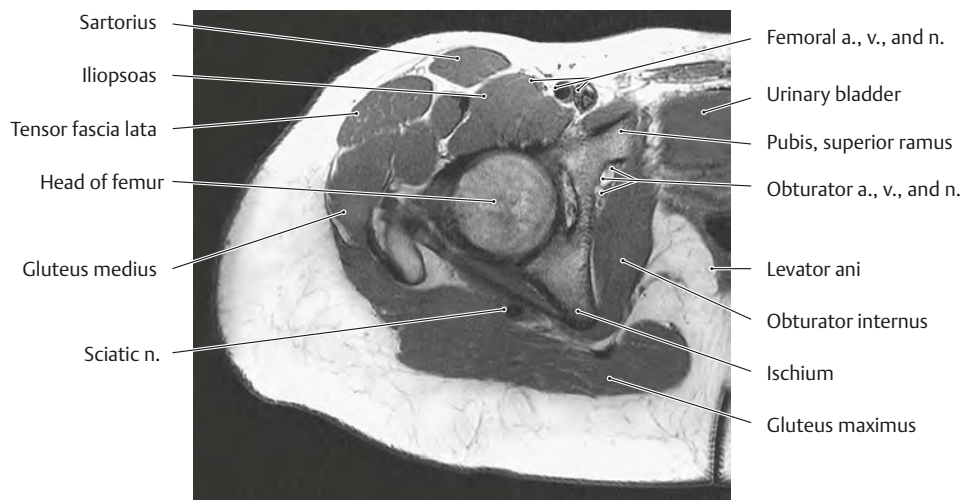
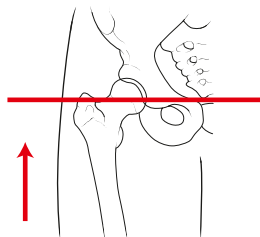
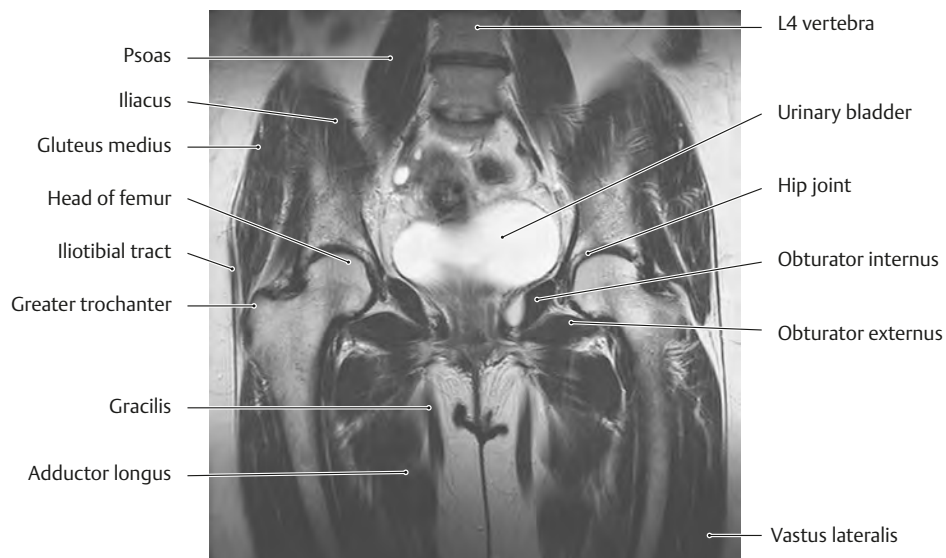
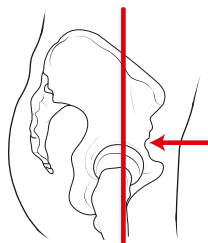


Fig. 35.7 MRI of the right hip joint

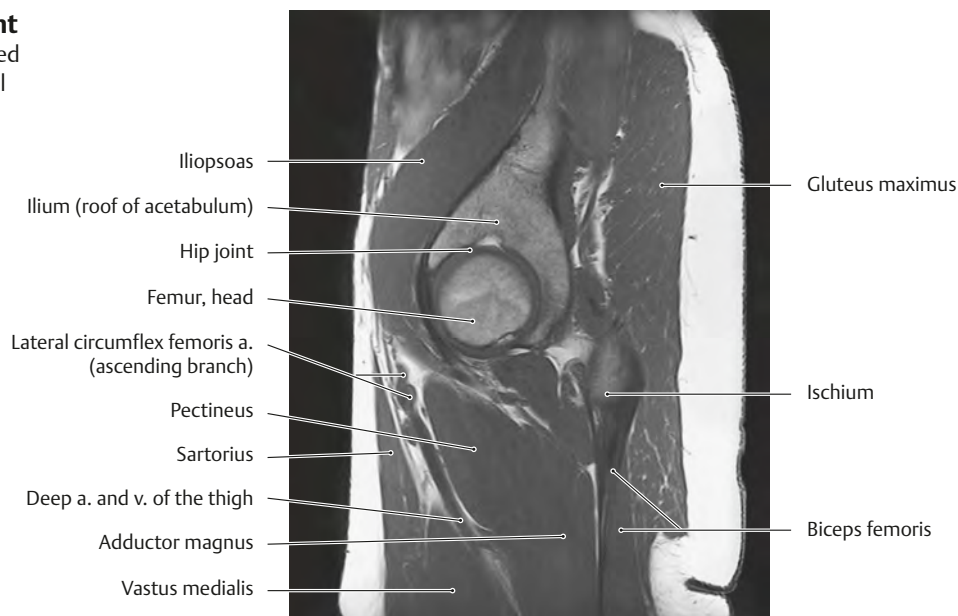
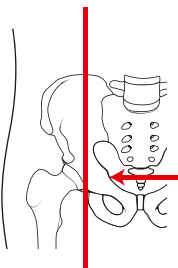
Transverse section, distal (inferior) view.
(Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

**Fig. 35.8 MRI of the hip joints**

Coronal section, anterior view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

**Fig. 35.9 MRI of the right hip joint**

Sagittal section, medial view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)



Radiographic Anatomy of the Lower Limb (III)

Fig. 35.10 Radiograph of the right knee joint

Anteroposterior view. (Reproduced courtesy of Klinik für Diagnostische Radiologie, Universitätsklinikum Schleswig Holstein, Campus Kiel; Prof. Dr. Med. S. Müller-Huelsbeck.)

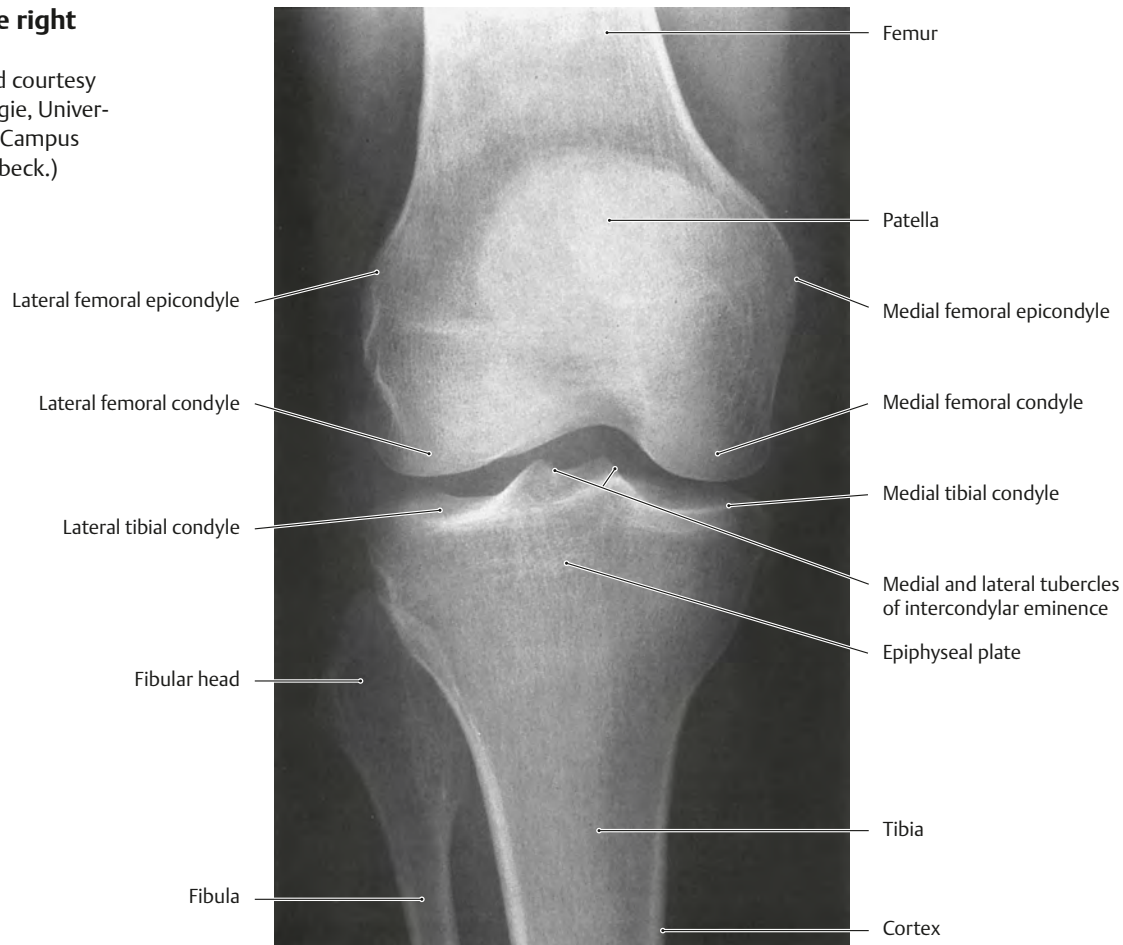
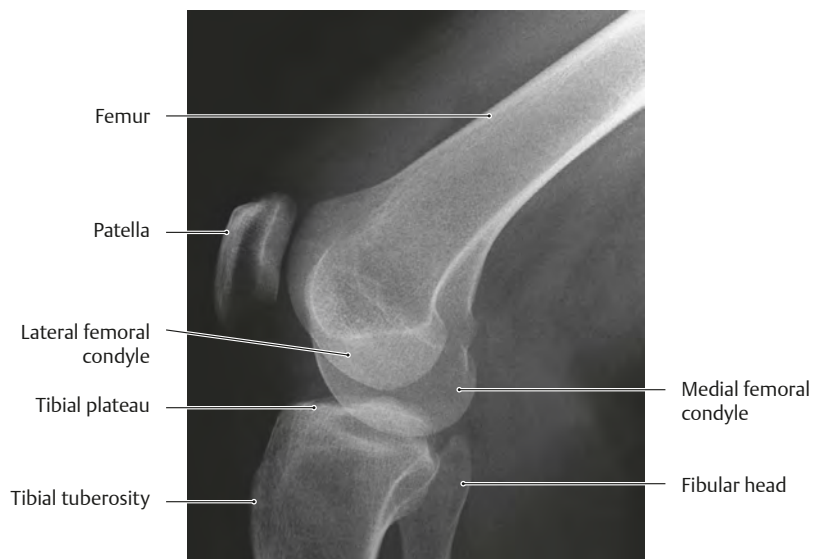
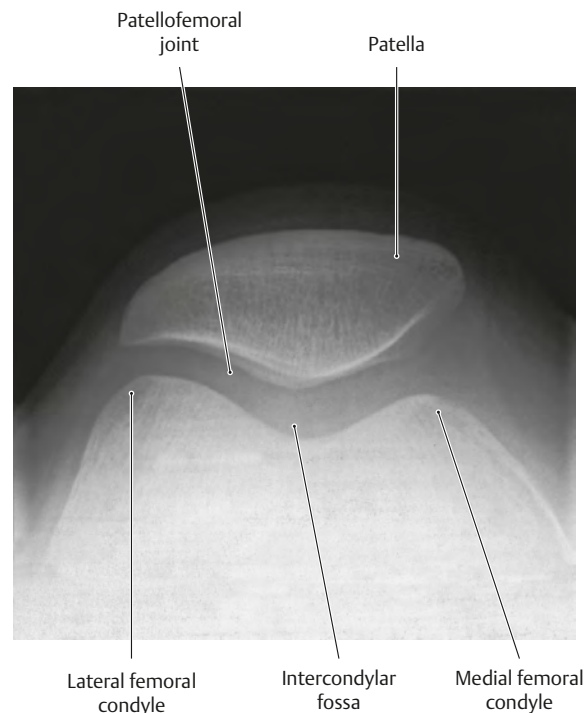


Fig. 35.11 Radiograph of the knee in flexion

(Reproduced courtesy of Klinik für Diagnostische Radiologie, Universitätsklinikum Schleswig Holstein, Campus Kiel; Prof. Dr. Med. S. Müller-Huelsbeck.)



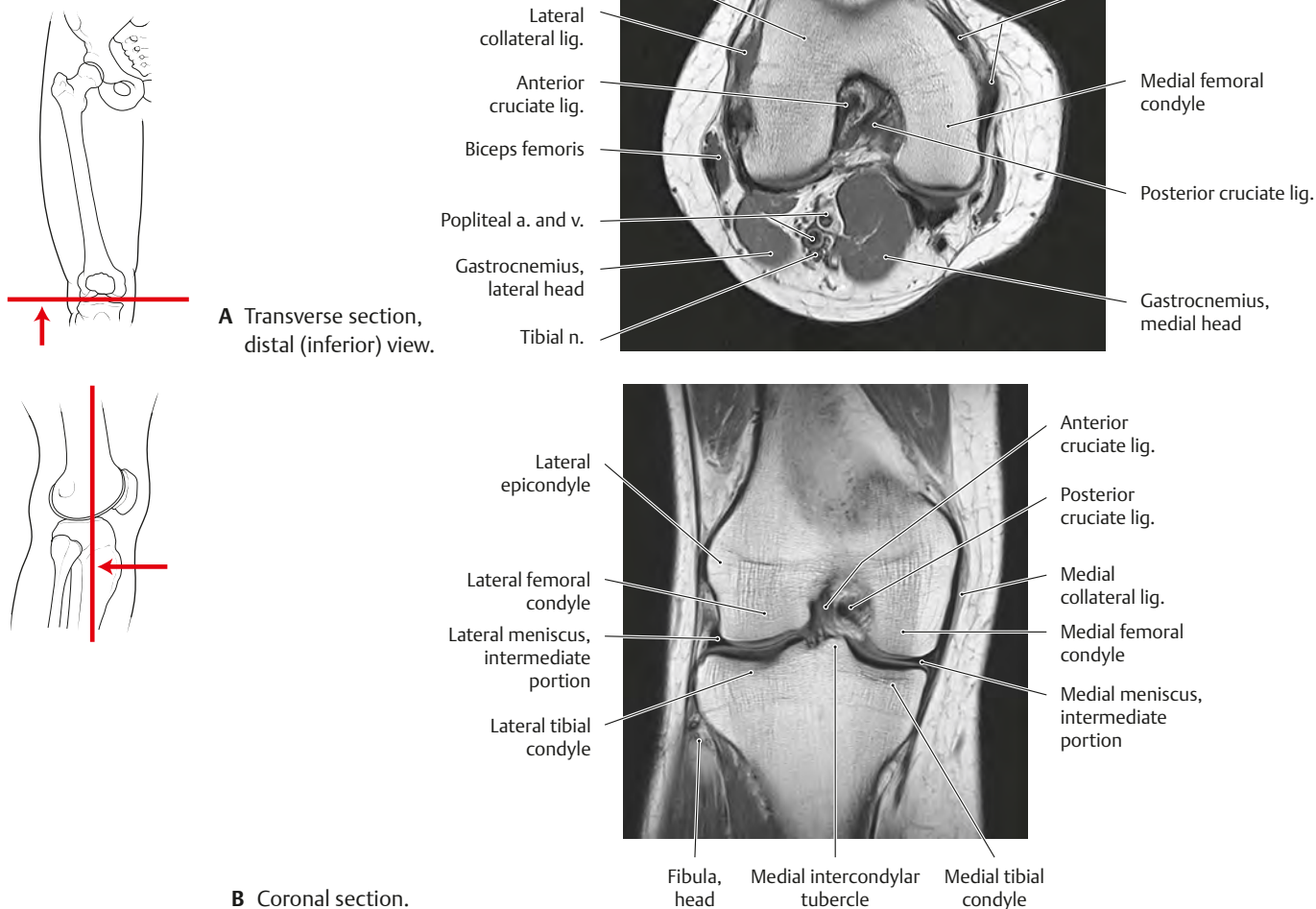
A Lateral view.



B Sunrise view.

Fig. 35.12 MRI of the knee joint

(Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

**Fig. 35.13 MRI of the knee joint**

Sagittal section. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

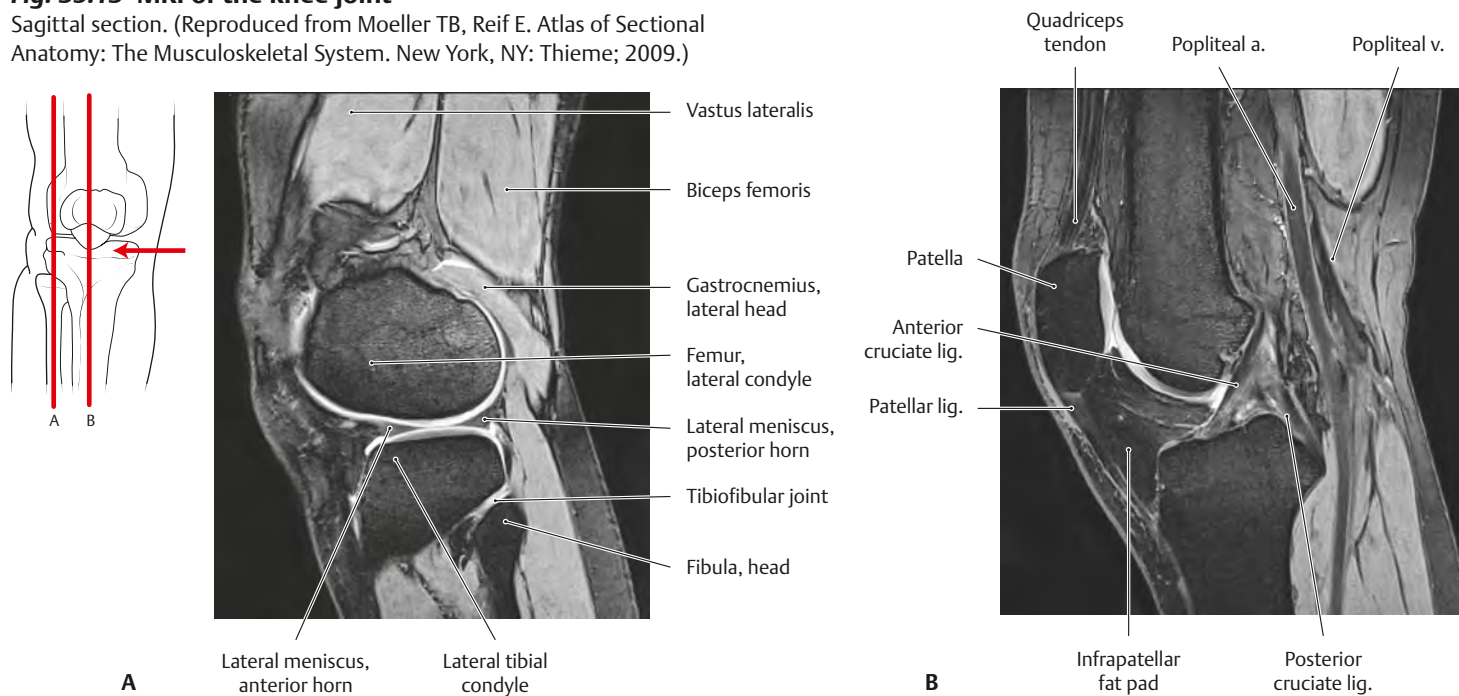


Fig. 35.14 Radiograph of the ankle

(Reproduced from Moeller TB, Reif E. Taschenatlas der Roentgenanatomie, 2nd ed. Stuttgart: Thieme; 1998.)

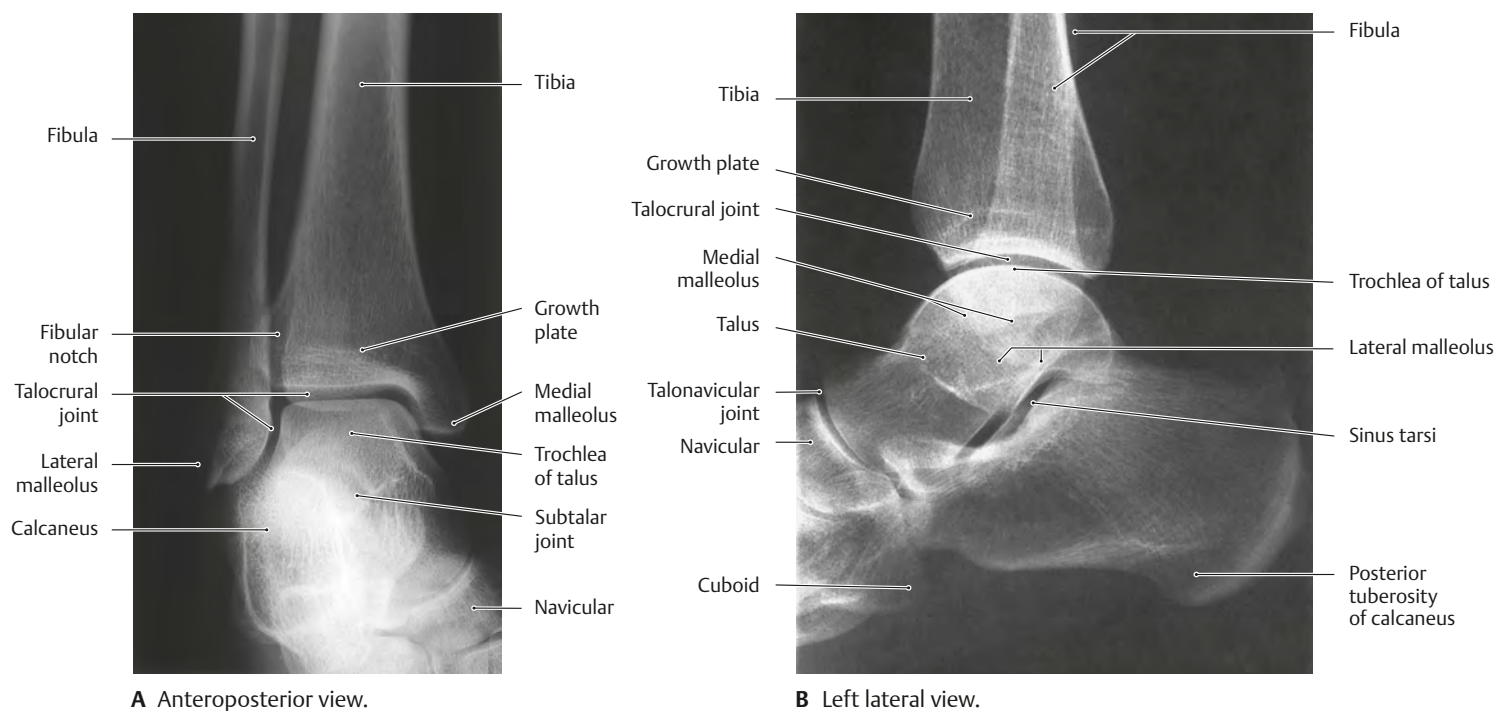


Fig. 35.15 Anterior-posterior view of the forefoot

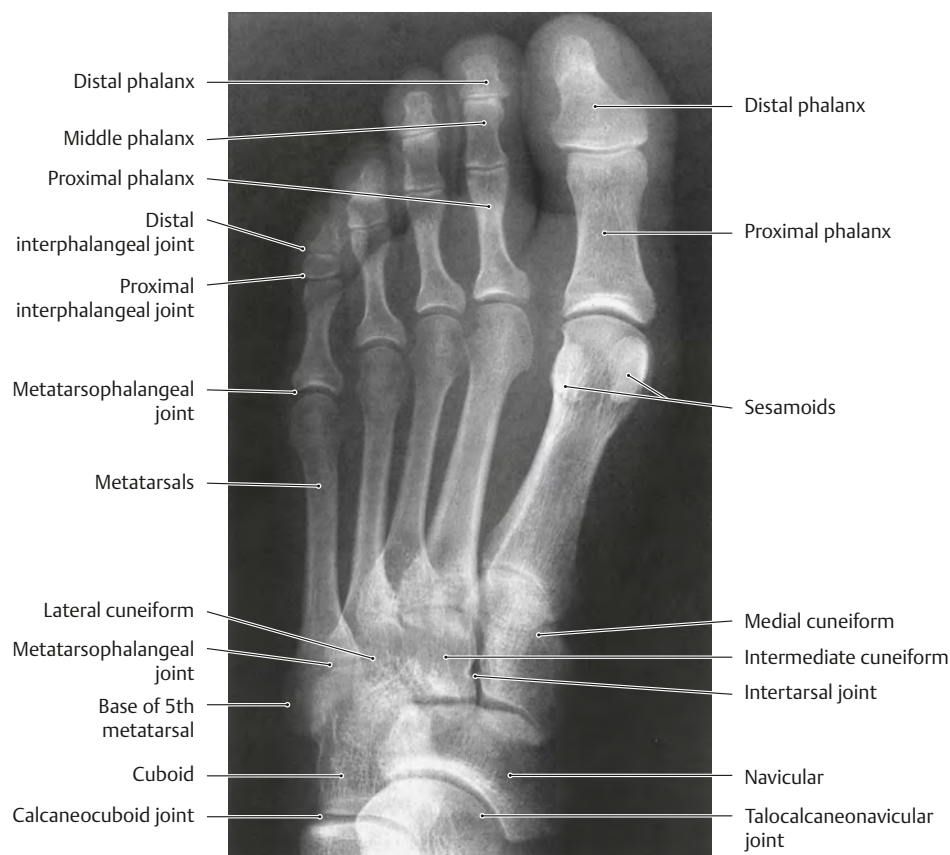
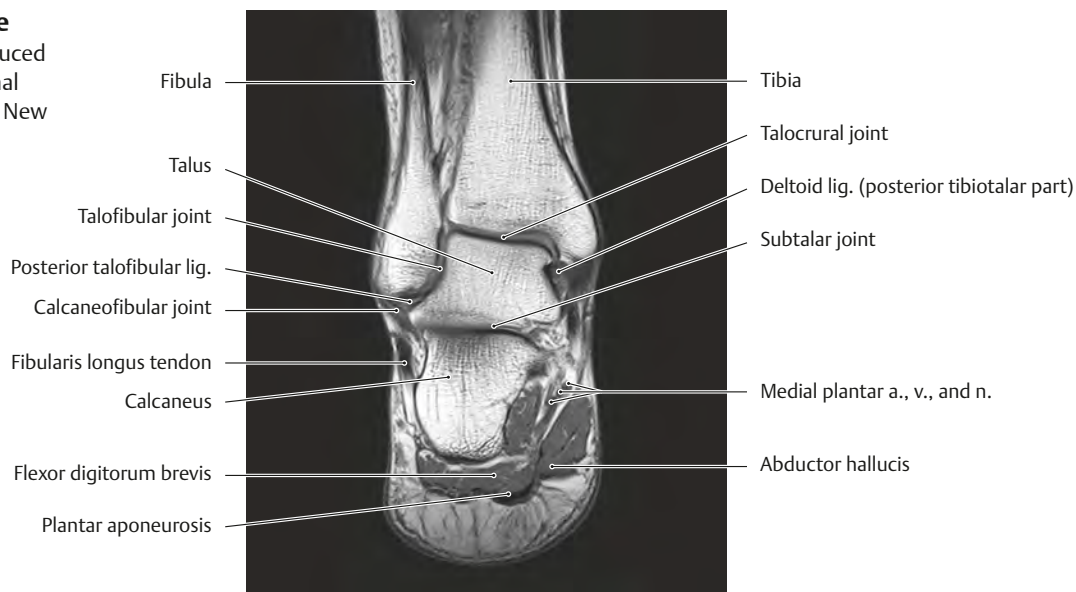
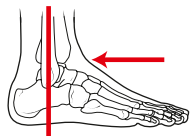
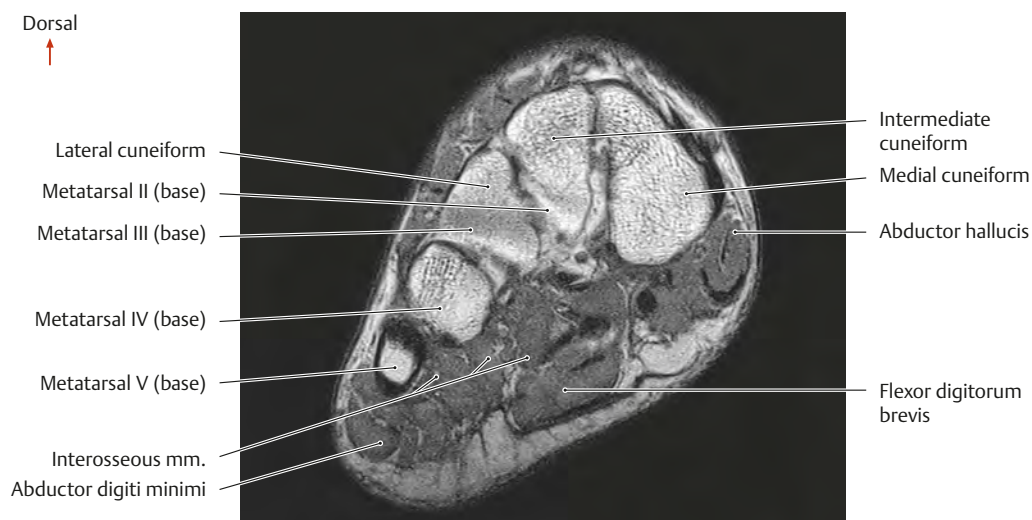
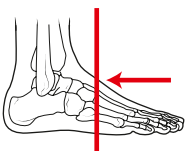


Fig. 35.16 MRI of the right ankle

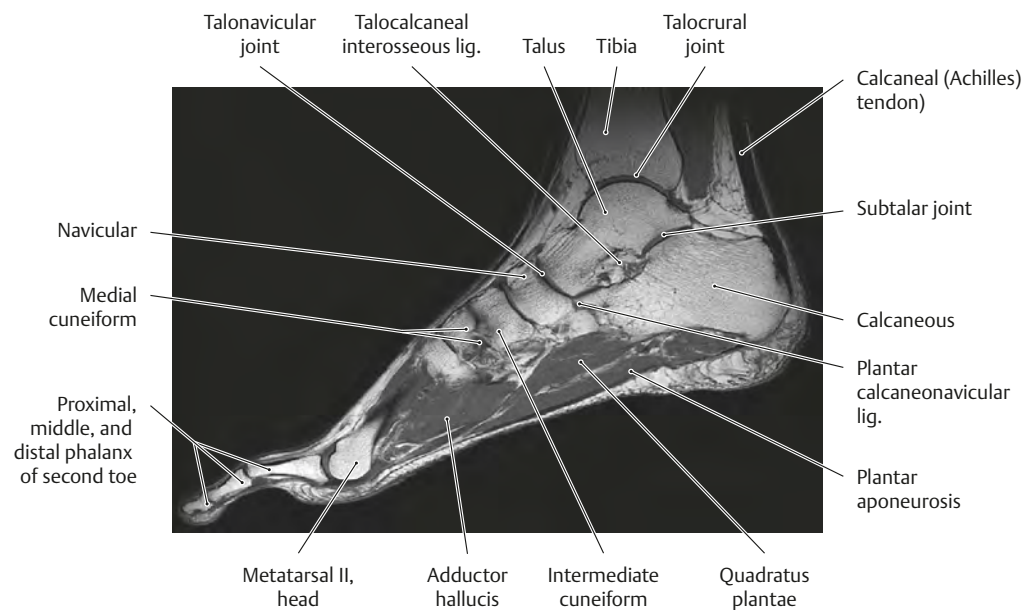
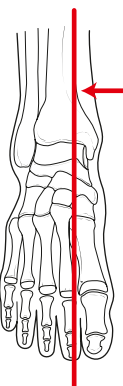
Coronal section, anterior view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

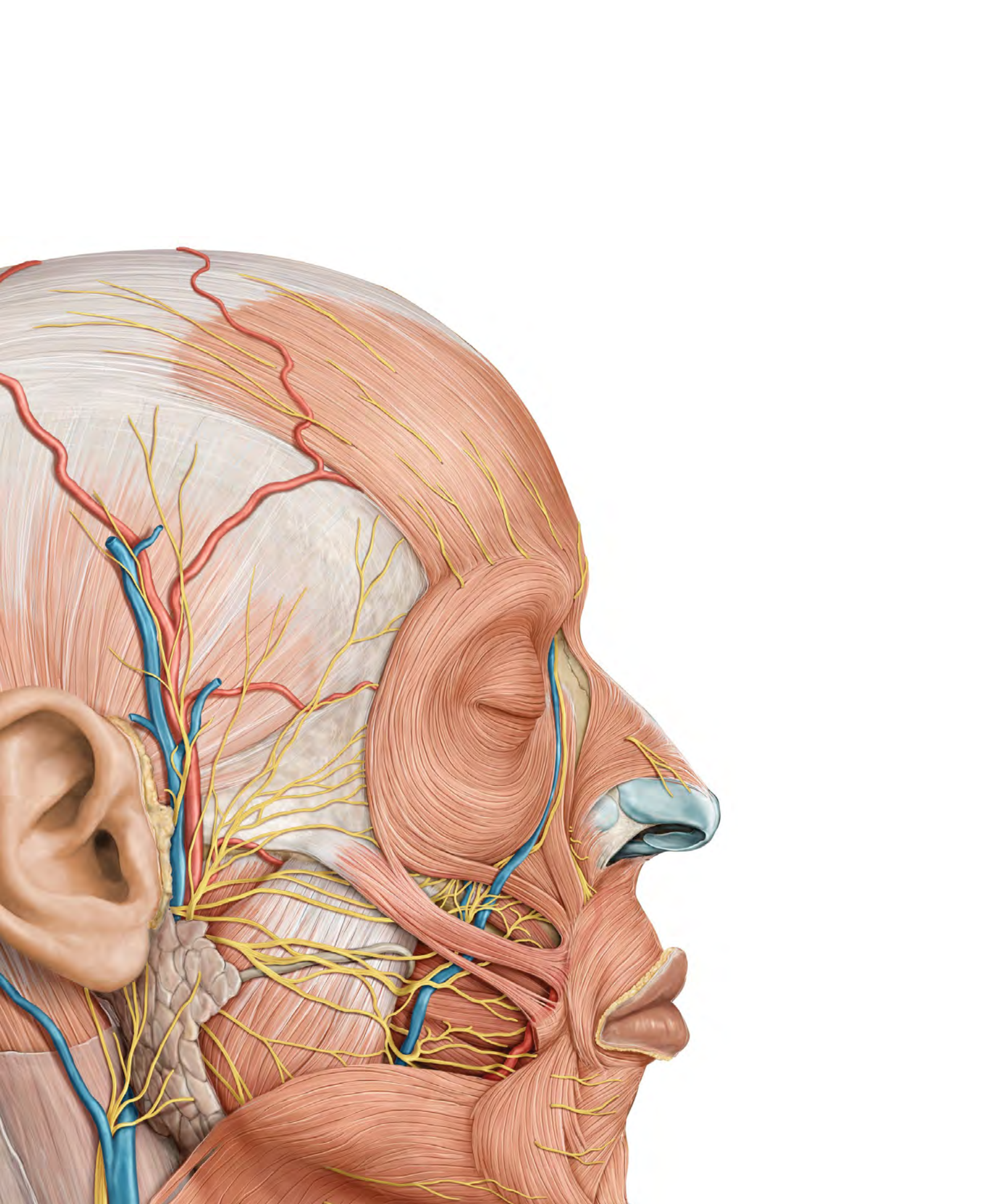
**Fig. 35.17 MRI of the right foot**

Coronal section, anterior (distal) view. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)

**Fig. 35.18 MRI of the right foot and ankle**

Sagittal section. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculoskeletal System. New York, NY: Thieme; 2009.)





Head & Neck

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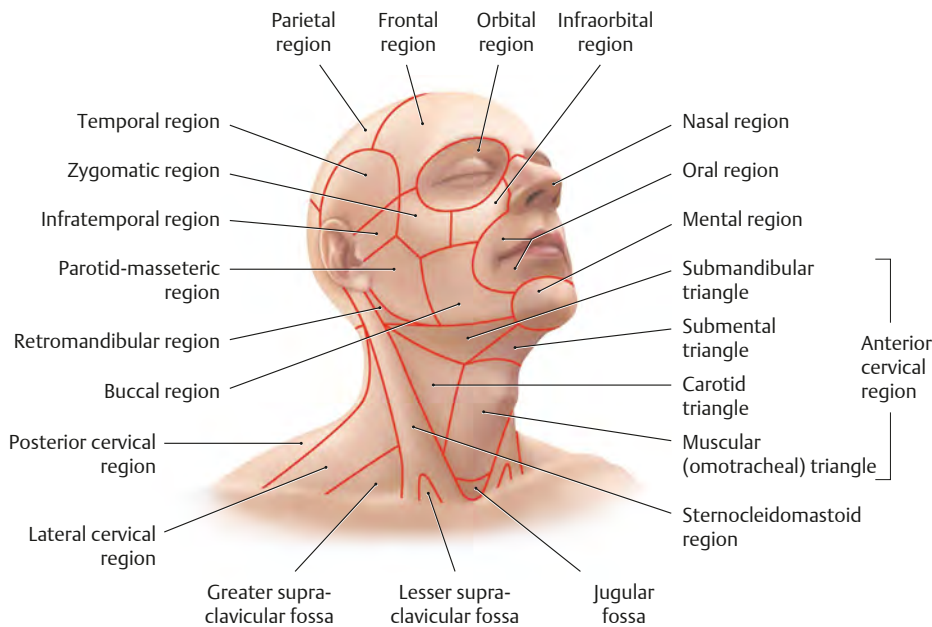
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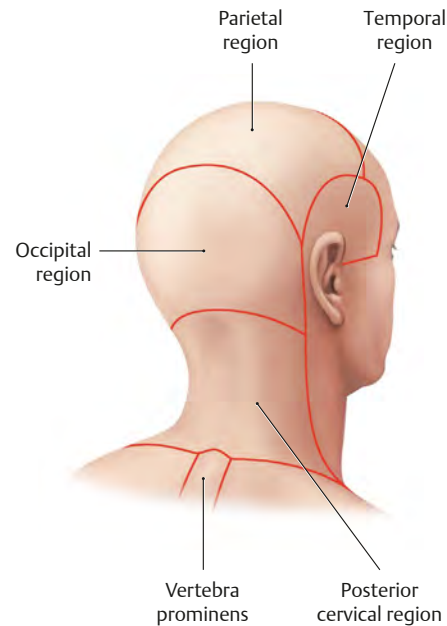
36 Surface Anatomy

Surface Anatomy

Fig. 36.1 Regions of the head and neck

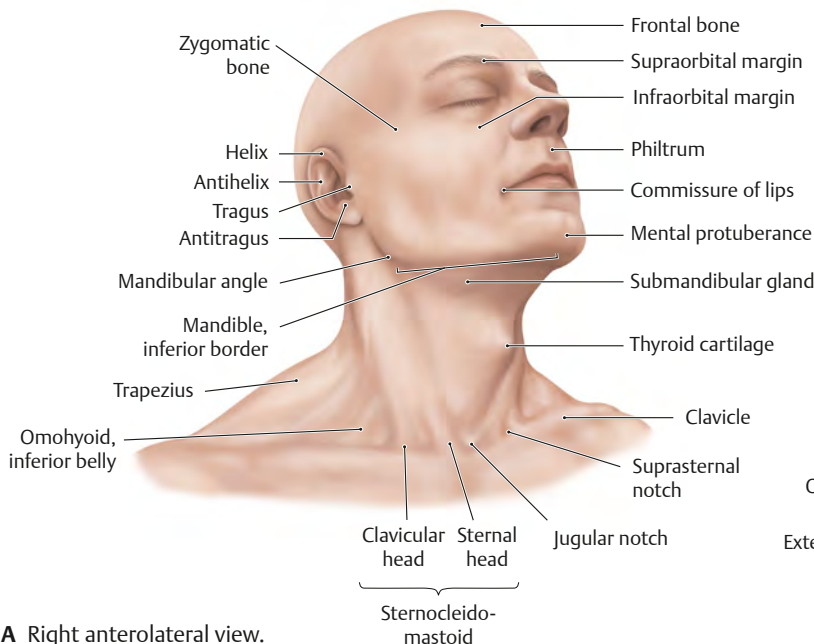


A Right anterolateral view.

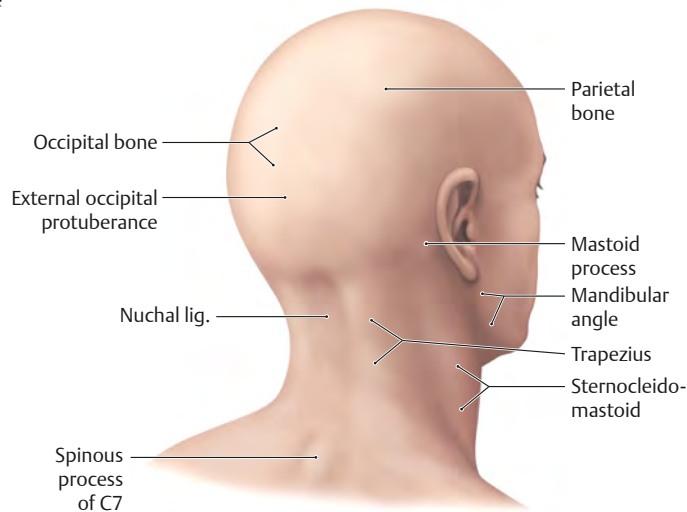


B Right posterolateral view.

Fig. 36.2 Surface anatomy of the head and neck

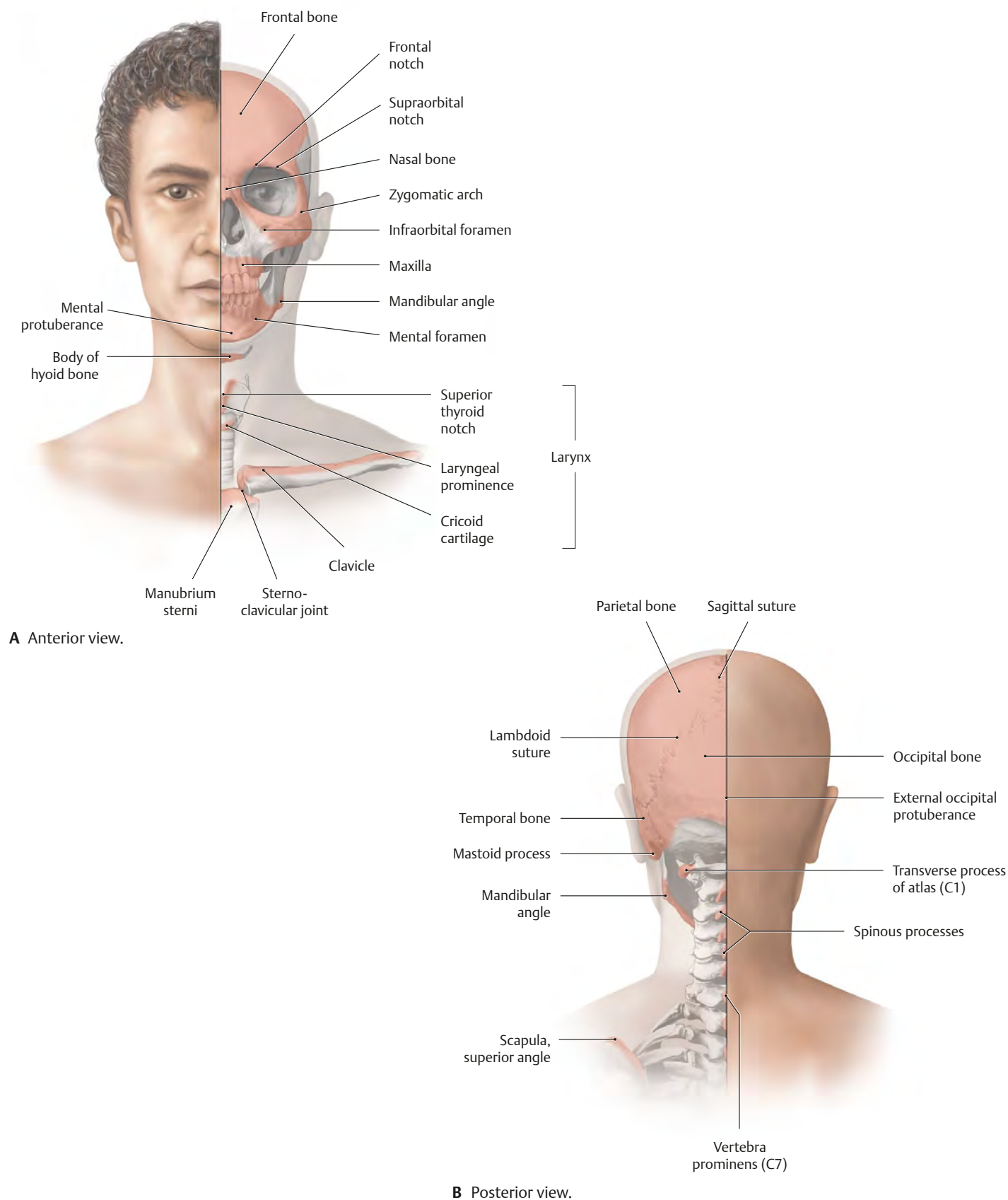


A Right anterolateral view.



B Right posterolateral view.

Fig. 36.3 Palpable bony prominences of the head and neck



37 Neck

Muscle Facts (I)

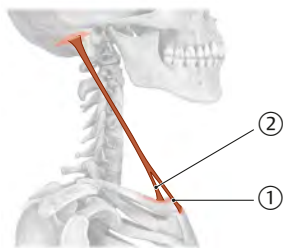
The bones, joints, and ligaments of the neck and the six topographic classes of neck muscles are covered here in this unit with the neck, or in Unit 1 with the back (see **Table 37.1**). However, some muscles in the same topographic class belong in different functional classes; for example, the platysma belongs to the muscles of facial expression; the

trapezius, to the muscles of the shoulder girdle; and the nuchal muscles, to the intrinsic back muscles. Note that the suboccipital muscles (short nuchal and craniovertebral joint muscles) are covered with the lateral (deep) muscles of the neck.

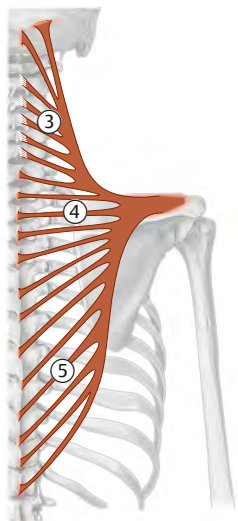
Table 37.1 Bones, joints, ligaments, and muscles of the neck			
Bones, joints, and ligaments			
Bones of the cervical spine	See pp. 8–9	Joints & ligaments of the craniovertebral junction	See pp. 18–19
Joints & ligaments of the cervical spine	See pp. 16–17, 20–21	Hyoid bone & larynx	Fig. 45.3, Fig. 37.18
Muscles			
I Superficial neck muscles		III Suprahyoid muscles	
Platysma, ①, ② sternocleidomastoid, ③, ④, ⑤ trapezius	Fig. 37.3	Digastric, geniohyoid, mylohyoid, stylohyoid	Fig. 37.4A
II Nuchal muscles (intrinsic back muscles)		IV Infrahyoid muscles	
⑥ Semispinalis capitis ⑦ Semispinalis cervicis	See p. 34	Sternohyoid, sternothyroid, thyrohyoid, omohyoid	Fig. 37.4B
⑧ Splenius capitis ⑨ Splenius cervicis	See p. 32	V Prevertebral muscles	
⑩ Longissimus capitis ⑪ Longissimus cervicis		Longus capitis, longus coli, rectus capitis anterior and lateralis	See p. 31 Fig. 37.6A
⑫ Iliocostalis cervicis		VI Lateral (deep) neck muscles	
Suboccipital muscles (short nuchal and craniovertebral joint muscles)	Fig. 37.6C	Anterior, middle, and posterior scalenes	Fig. 37.6B

Fig. 37.1 Superficial neck muscles schematic

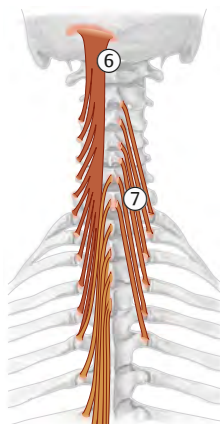
See Table 37.2 for details.



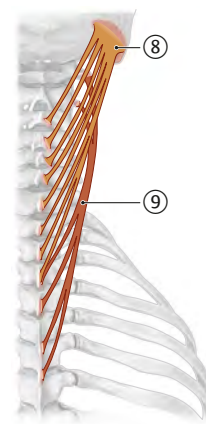
A Sternocleidomastoid.



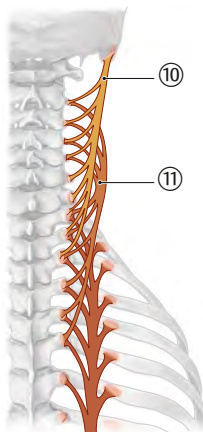
B Trapezius.



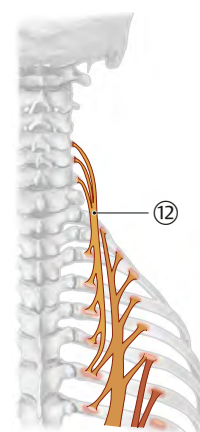
A Semispinalis.



B Splenius.



C Longissimus.



D Iliocostalis.

Fig. 37.2 Nuchal muscles schematic

Fig. 37.3 Superficial neck muscles

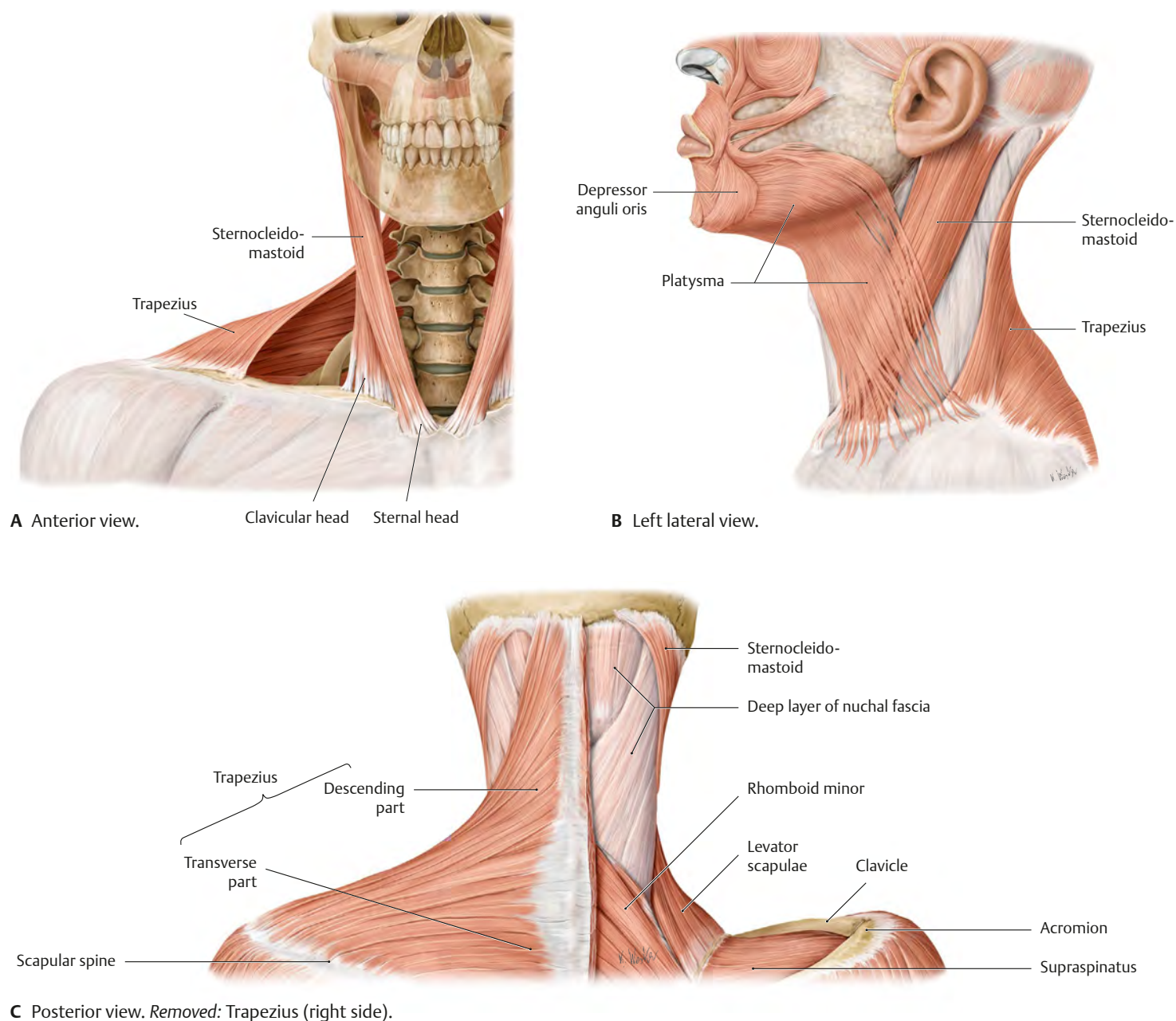


Table 37.2

Superficial neck muscles

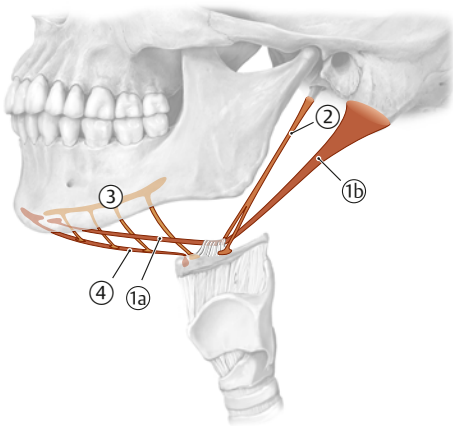
Muscle		Origin	Insertion	Innervation	Action
Platysma		Skin over lower neck and upper lateral thorax	Mandible (inferior border), skin over lower face and angle of mouth	Cervical branch of facial n. (CN VII)	Depresses and wrinkles skin of lower face and mouth, tenses skin of neck, aids forced depression of mandible
Sternocleidomastoid	① Sternal head	Sternum (manubrium)	Temporal bone (mastoid process), occipital bone (superior nuchal line)	Motor: Accessory n. (CN XI) Proprioception: Cervical plexus (C2, C3, [C4])	Unilateral: Tilts head to same side, rotates head to opposite side Bilateral: Extends head, aids in respiration when head is fixed
	② Clavicular head	Clavicle (medial one third)			
Trapezius	③ Descending part*	Occipital bone, spinous processes of C1–C7	Clavicle (lateral one third)		Draws scapula obliquely upward, rotates glenoid cavity superiorly

* The transverse ④ and ascending ⑤ parts are described on p. 320.

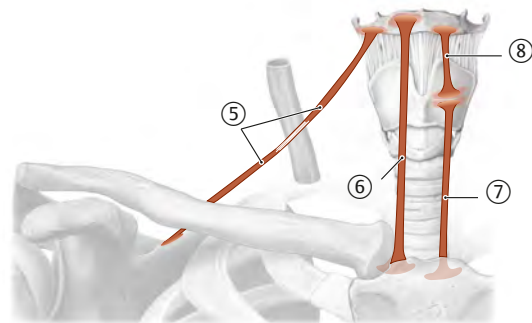
Muscle Facts (II)

Table 37.3		Suprahyoid muscles				
The suprahyoid muscles are also considered accessory muscles of mastication.						
Muscle		Origin	Insertion		Innervation	Action
Digastric	1a Anterior belly	Mandible (digastric fossa)	Hyoid bone (body)	Via an intermediate tendon with a fibrous loop	Mylohyoid n. (from CN V ₃)	Elevates hyoid bone (during swallowing), assists in opening mandible
	1b Posterior belly	Temporal bone (mastoid notch, medial to mastoid process)			Facial n. (CN VII)	
2 Stylohyoid		Temporal bone (styloid process)		Via a split tendon		
3 Mylohyoid		Mandible (mylohyoid line)		Via median tendon of insertion (mylohyoid raphe)	Mylohyoid n. (from CN V ₃)	Tightens and elevates oral floor, draws hyoid bone forward (during swallowing), assists in opening mandible and moving it side to side (during mastication)
4 Geniohyoid		Mandible (inferior mental spine)		Directly	Anterior ramus of C1 via hypoglossal n. (CN XII)	Draws hyoid bone forward (during swallowing), assists in opening mandible

Fig. 37.4 Suprahyoid and infrahyoid muscles



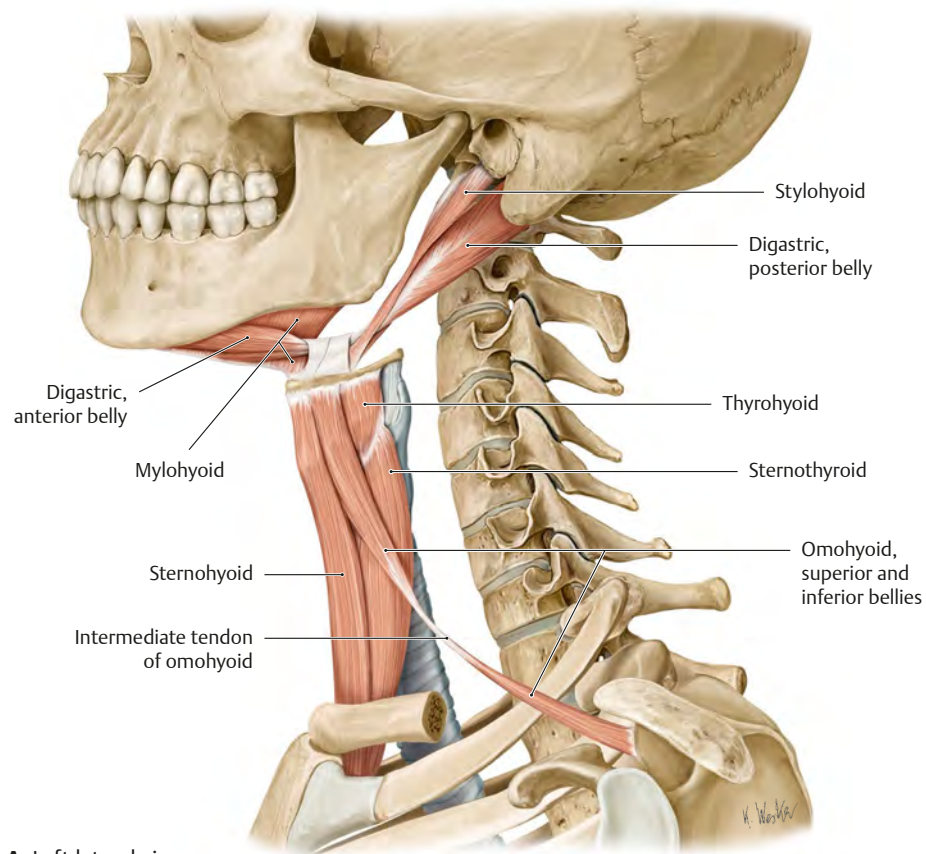
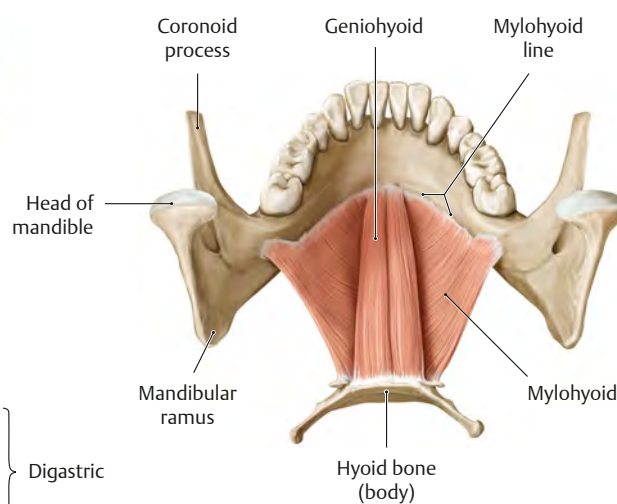
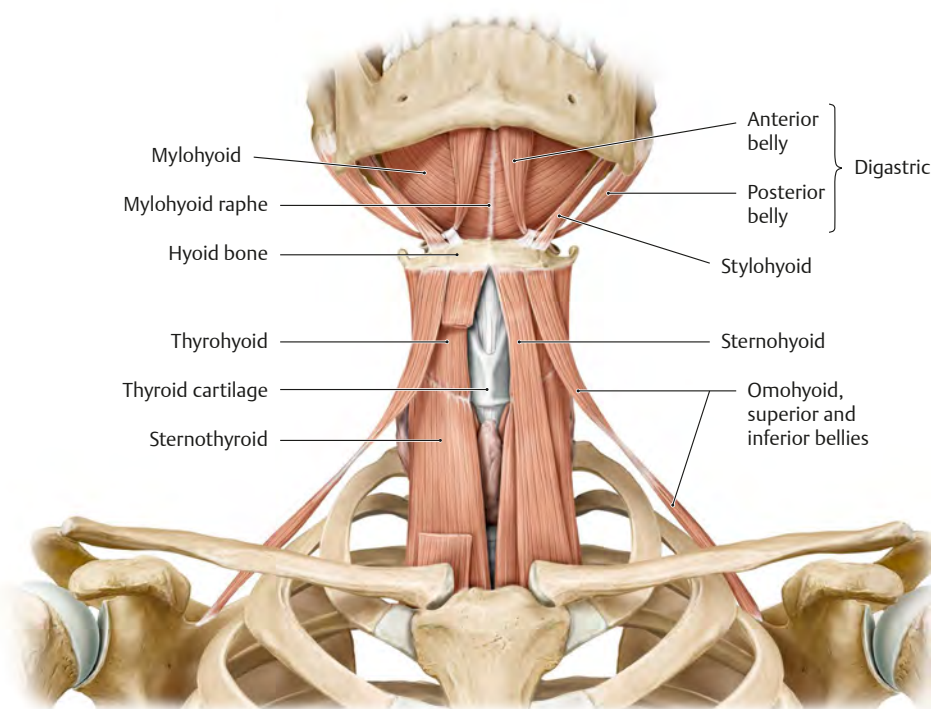
A Suprahyoid muscles, left lateral view.



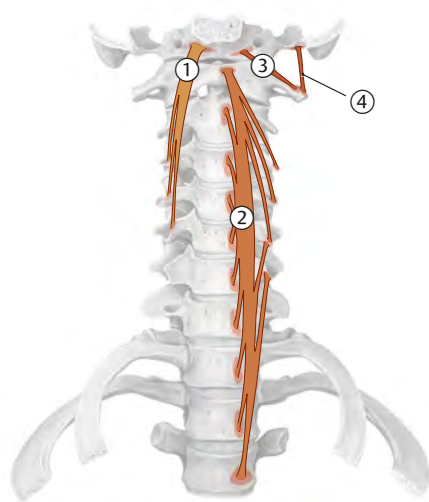
B Infrahyoid muscles, anterior view.

Table 37.4 Infrahyoid muscles				
Muscle	Origin	Insertion	Innervation	Action
5 Omohyoid	Scapula (superior border) – inferior belly	Hyoid bone (body) – superior belly	Ansa cervicalis (C1–C3) of cervical plexus	Depresses (fixes) hyoid, draws larynx and hyoid down for phonation and terminal phases of swallowing*
6 Sternohyoid	Manubrium and sternoclavicular joint (posterior surface)			
7 Sternothyroid	Manubrium (posterior surface)	Thyroid cartilage (oblique line)	Ansa cervicalis (C1–C3) of cervical plexus	
8 Thyrohyoid	Thyroid cartilage (oblique line)	Hyoid bone (body)	Anterior ramus of C1 via hypoglossal n. (CN XII)	Depresses and fixes hyoid, raises the larynx during swallowing

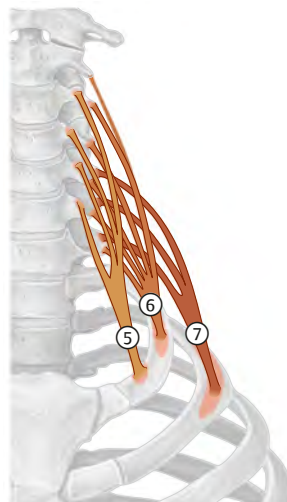
* The omohyoid also tenses the cervical fascia (via its intermediate tendon).

Fig. 37.5 Suprahyoid and infrahyoid muscles**A** Left lateral view.**B** Mylohyoid and geniohyoid (oral floor), posterosuperior view.**C** Anterior view. The sternohyoid has been cut (right).

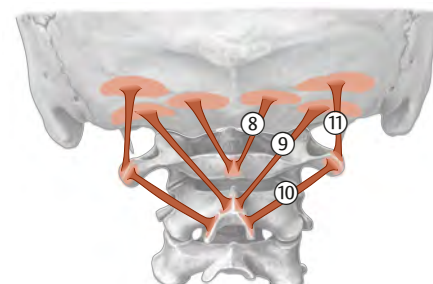
Muscle Facts (III)



A Prevertebral muscles, anterior view.



B Scalene muscles, anterior view.



C Suboccipital muscles, posterior view.

Fig. 37.6 Deep muscles of the neck

Table 37.5 Deep muscles of the neck

Muscle		Origin	Insertion	Innervation	Action
Prevertebral muscles					
① Longus capitis		C3–C6 (anterior tubercles of transverse processes)	Occipital bone (basilar part)	Anterior rami of C1–C3	Flexion of head at atlanto-occipital joints
② Longus colli	Vertical (intermediate) part	C5–T3 (anterior surfaces of vertebral bodies)	C2–C4 (anterior surfaces)	Anterior rami of C2–C6	<i>Unilateral:</i> Tilts and rotates cervical spine to opposite side <i>Bilateral:</i> Forward flexion of cervical spine
	Superior oblique part	C3–C5 (anterior tubercles of transverse processes)	Atlas (anterior tubercle)		
	Inferior oblique part	T1–T3 (anterior surfaces of vertebral bodies)	C5–C6 (anterior tubercles of transverse processes)		
③ Rectus capitis anterior		C1 (lateral mass)	Occipital bone (basilar part)	Anterior rami of C1 and C2	<i>Unilateral:</i> Lateral flexion of the head at the atlanto-occipital joint <i>Bilateral:</i> Flexion of the head at the atlanto-occipital joint
④ Rectus capitis lateralis		C1 (transverse process)	Occipital bone (basilar part, lateral to occipital condyles)		
Scalene muscles					
⑤ Anterior scalene		C3–C6 (anterior tubercles of transverse processes)	1st rib (scalene tubercle)	Anterior rami of C4–C6	<i>With ribs mobile:</i> Elevates upper ribs (during forced inspiration) <i>With ribs fixed:</i> Flexes cervical spine to same side (unilateral), flexes neck (bilateral)
⑥ Middle scalene		C1–C2 (transverse processes), C3–C7 (posterior tubercles of transverse processes)	1st rib (posterior to groove for subclavian a.)	Anterior rami of C3–C8	
⑦ Posterior scalene		C5–C7 (posterior tubercles of transverse processes)	2nd rib (outer surface)	Anterior rami of C6–C8	
Suboccipital muscles (short nuchal and craniovertebral joint muscles)					
⑧ Rectus capitis posterior minor		C1 (posterior tubercle)	Occipital bone (inner third of inferior nuchal line)	Posterior ramus of C1 (suboccipital n.)	<i>Unilateral:</i> Rotates head to same side <i>Bilateral:</i> Extends head
⑨ Rectus capitis posterior major		C2 (spinous process)	Occipital bone (middle third of inferior nuchal line)		
⑩ Obliquus capitis inferior			C1 (transverse process)		<i>Unilateral:</i> Tilts head to same side, rotates it to opposite side <i>Bilateral:</i> Extends head
⑪ Obliquus capitis superior		C1 (transverse process)	Occipital bone (above insertion of rectus capitis posterior major)		

Fig. 37.7 Deep muscles of the neck

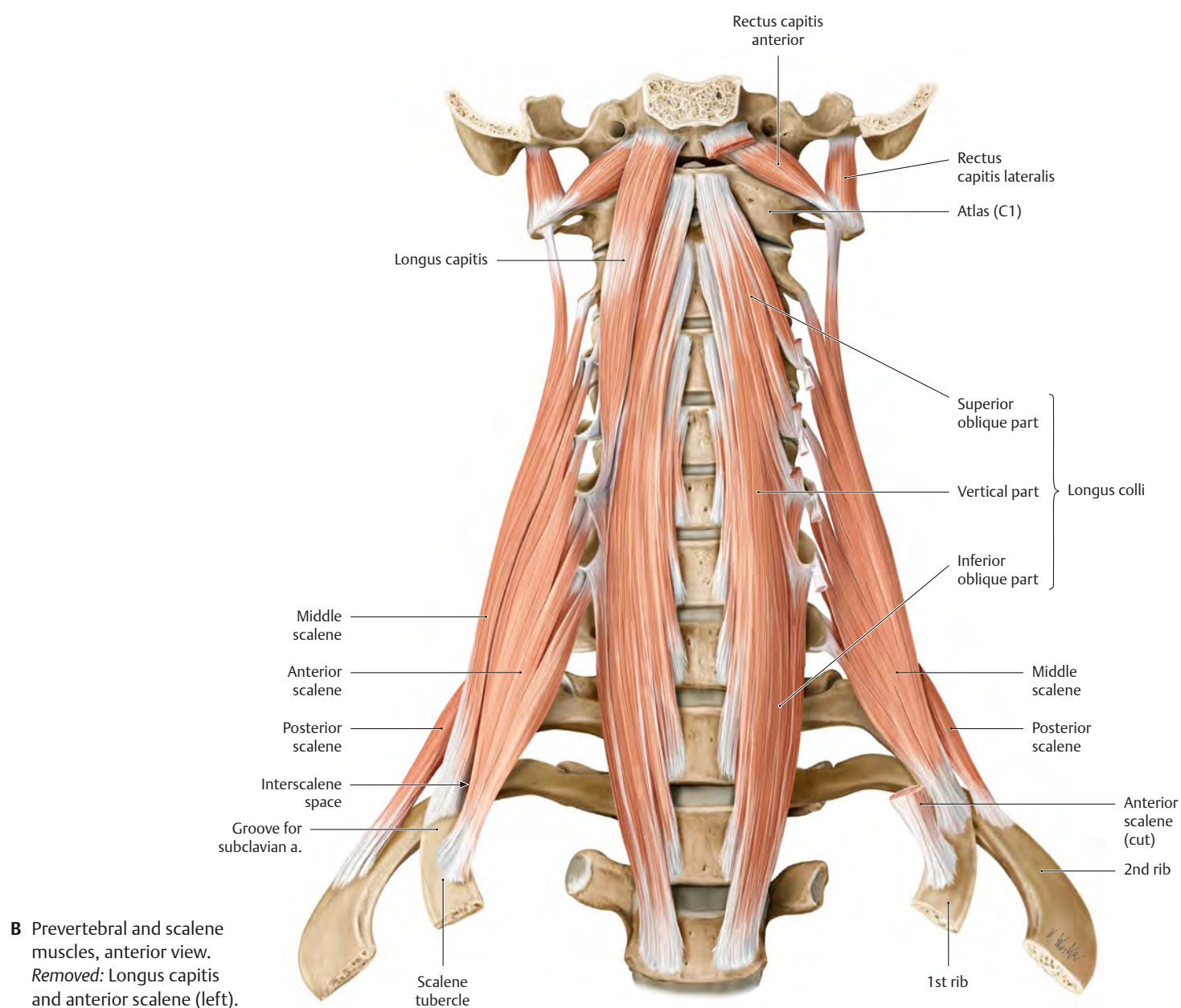
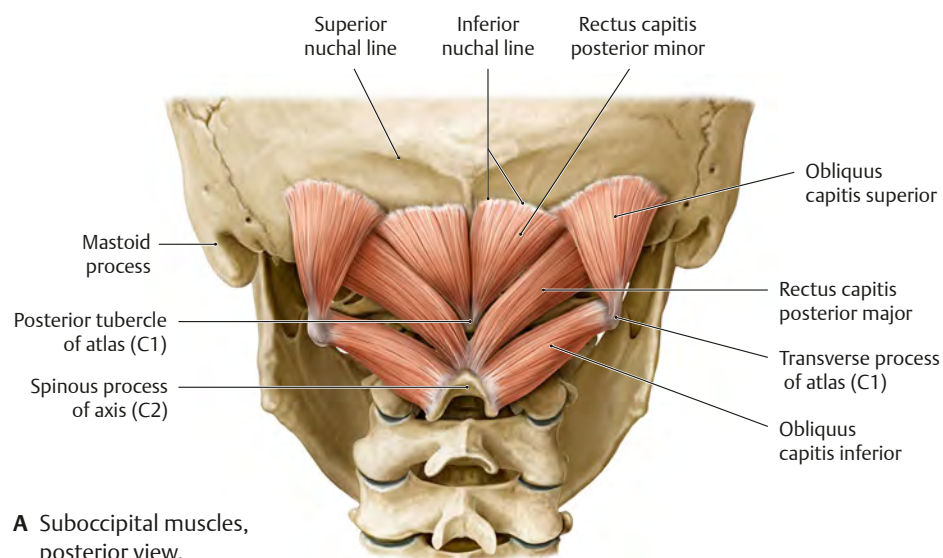


Fig. 37.8 Arteries of the neck

Left lateral view. The structures of the neck are primarily supplied by the external carotid artery (anterior branches) and the subclavian artery (vertebral artery, thyrocervical trunk, and costocervical trunk).

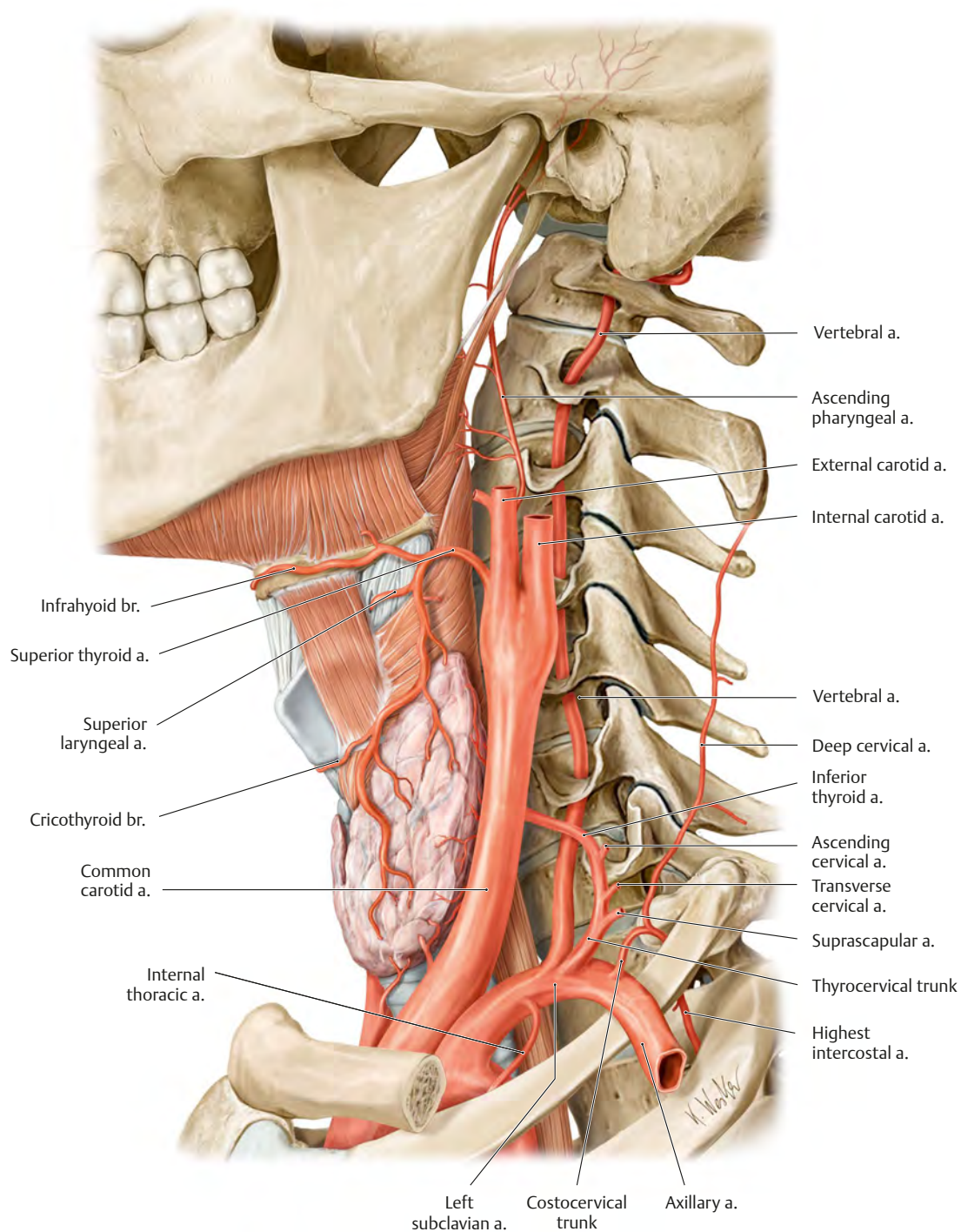
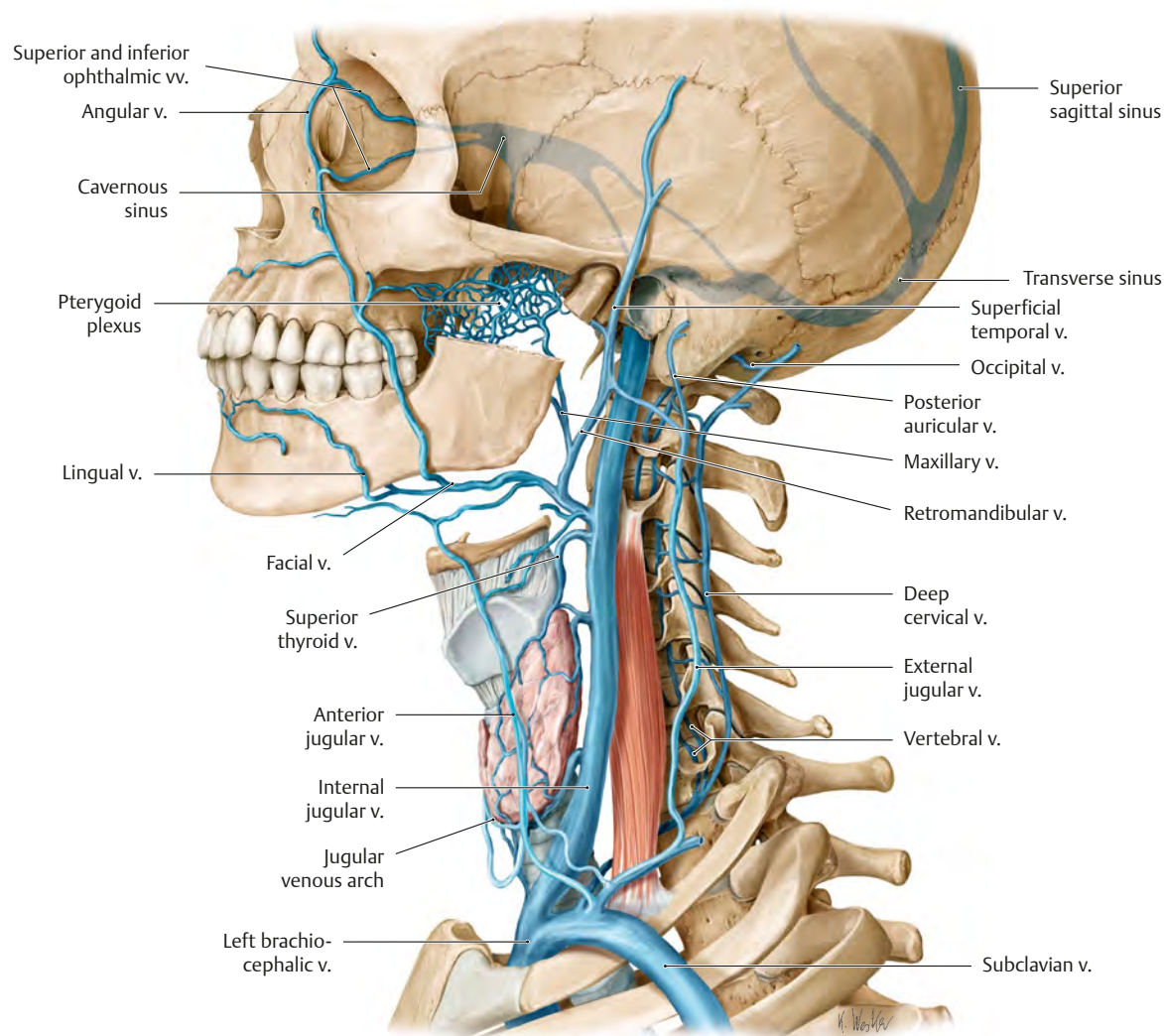
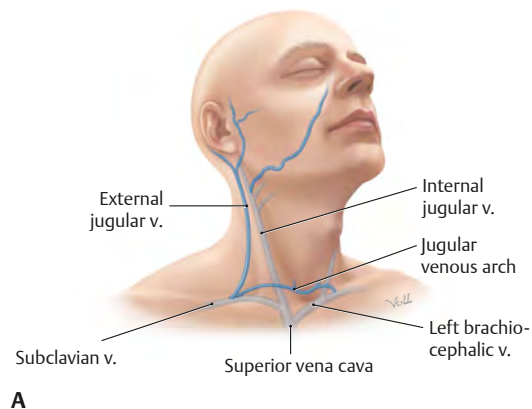
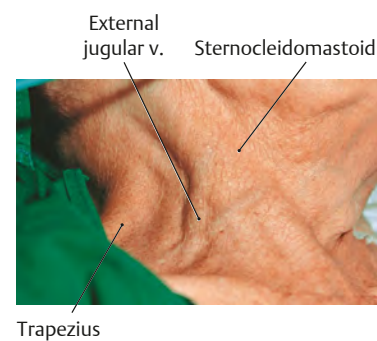


Fig. 37.9 Veins of the neck

Left lateral view. The principal veins of the neck are the internal, external, and anterior jugular veins.

**Clinical box 37.1****Impeded blood flow and veins of the neck**

When clinical factors (e.g., chronic lung disease, mediastinal tumors, or infections) impede the flow of blood to the right heart, blood dams up in the superior vena cava and, consequently, the jugular veins (A). This causes conspicuous swelling in the jugular (and sometimes more minor) veins (B).

**A****B**

Lymphatics of the Neck

Fig. 37.10 Lymphatic drainage regions
Right lateral view.

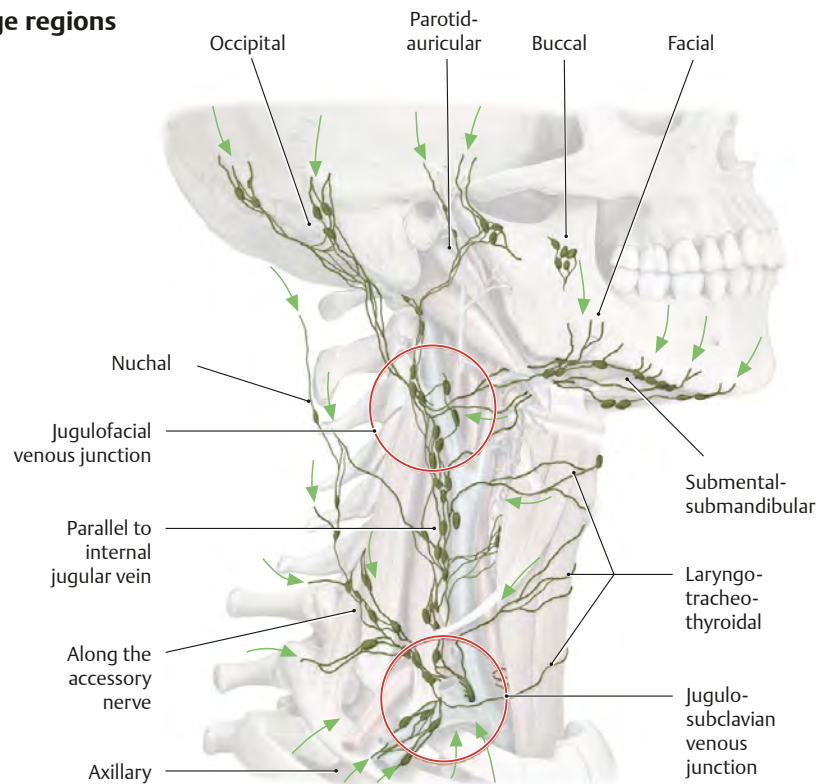
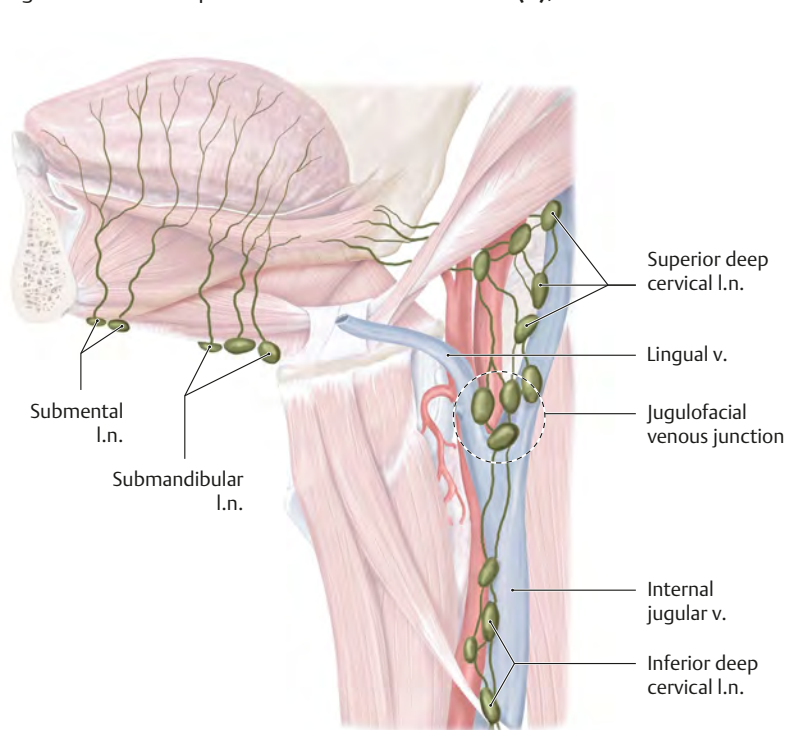


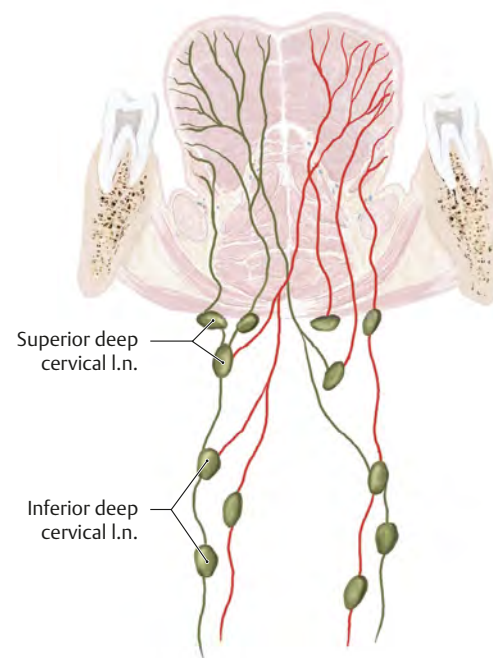
Fig. 37.11 Lymphatic drainage of the tongue and oral floor

Lymph flows into the submental and submandibular lymph nodes of the tongue and oral floor, which ultimately drain into the jugular lymph nodes along the internal jugular vein. Because the lymph nodes receive drainage from both the ipsilateral and contralateral sides (**B**), tumor

cells may become widely disseminated in this region (e.g., metastatic squamous cell carcinoma, especially on the lateral border of the tongue, frequently metastasizes to the opposite side).



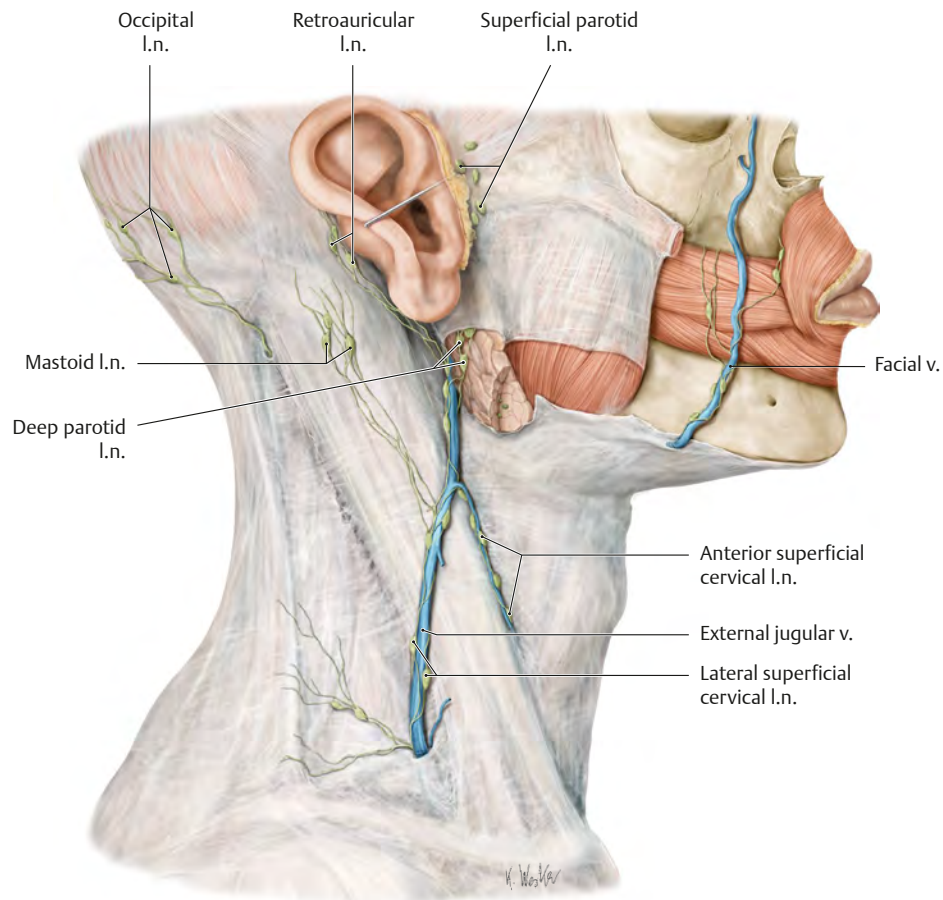
A Lateral view.



B Coronal section showing that lymphatic drainage from one side of the tongue can drain to either side of the neck.

Fig. 37.12 Superficial cervical lymph nodes

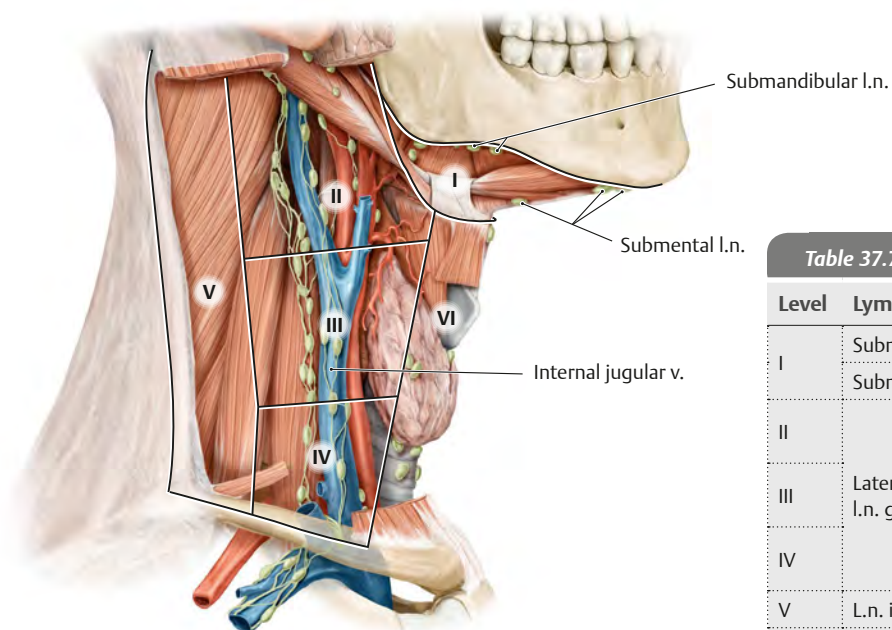
Right lateral view.

**Table 37.6****Superficial cervical lymph nodes**

Lymph nodes (l.n.)	Drainage region
Retroauricular l.n.	Occiput
Occipital l.n.	
Mastoid l.n.	
Superficial parotid l.n.	Parotid-auricular region
Deep parotid l.n.	
Anterior superficial cervical l.n.	Sternocleidomastoid region
Lateral superficial cervical l.n.	

Fig. 37.13 Deep cervical lymph nodes

Right lateral view.

**Table 37.7****Deep cervical lymph nodes**

Level	Lymph nodes (l.n.)	Drainage region
I	Submental l.n.	Face
	Submandibular l.n.	
II	Lateral jugular l.n. group	Upper lateral group
III		Middle lateral group
IV		Lower lateral group
V	L.n. in posterior cervical triangle	Nuchal region
VI	Anterior cervical l.n.	Laryngo-tracheo-thyroidal region

Innervation of the Neck

Table 37.8 Branches of the spinal nerves in the neck				
Posterior (dorsal) ramus				
	Nerve	Sensory function	Motor function	
C1	Suboccipital n.	No C1 dermatome	Innervate intrinsic nuchal muscles	
C2	Greater occipital n.	Innervate C2 dermatome		
C3	3rd occipital n.	Innervate C3 dermatome		
Anterior (ventral) ramus				
	Sensory branches	Sensory function	Motor branches	Motor function
C1	—	—	Form ansa cervicalis (motor part of cervical plexus)	Innervate infrahyoid muscles (except thyrohyoid)
C2	Lesser occipital n.	Form sensory part of cervical plexus, innervate anterior and lateral neck		
C2–C3	Great auricular n. Transverse cervical n.			
C3–C4	Supraclavicular nn.		Contribute to phrenic n.*	Innervate diaphragm and pericardium*
* The anterior roots of C3–C5 combine to form the phrenic nerve (see p. 66).				

* The anterior roots of C3–C5 combine to form the phrenic nerve (see p. 66).

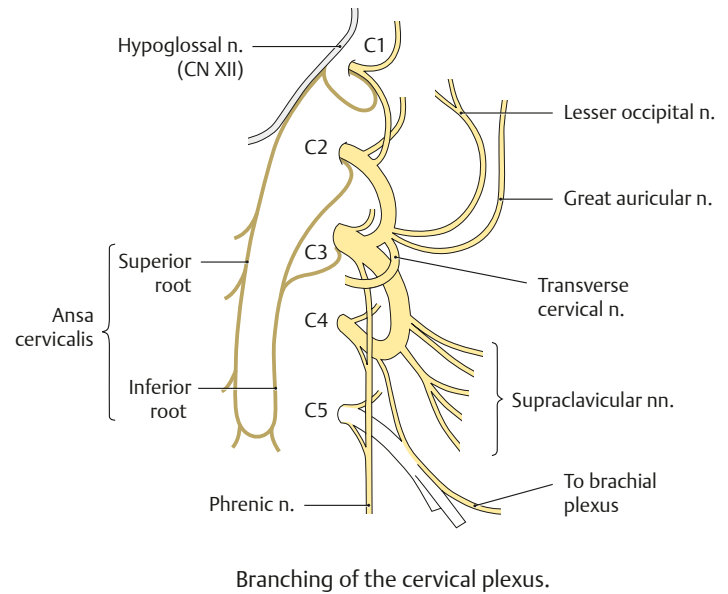


Fig. 37.14 Sensory innervation of the nuchal region

Posterior view.

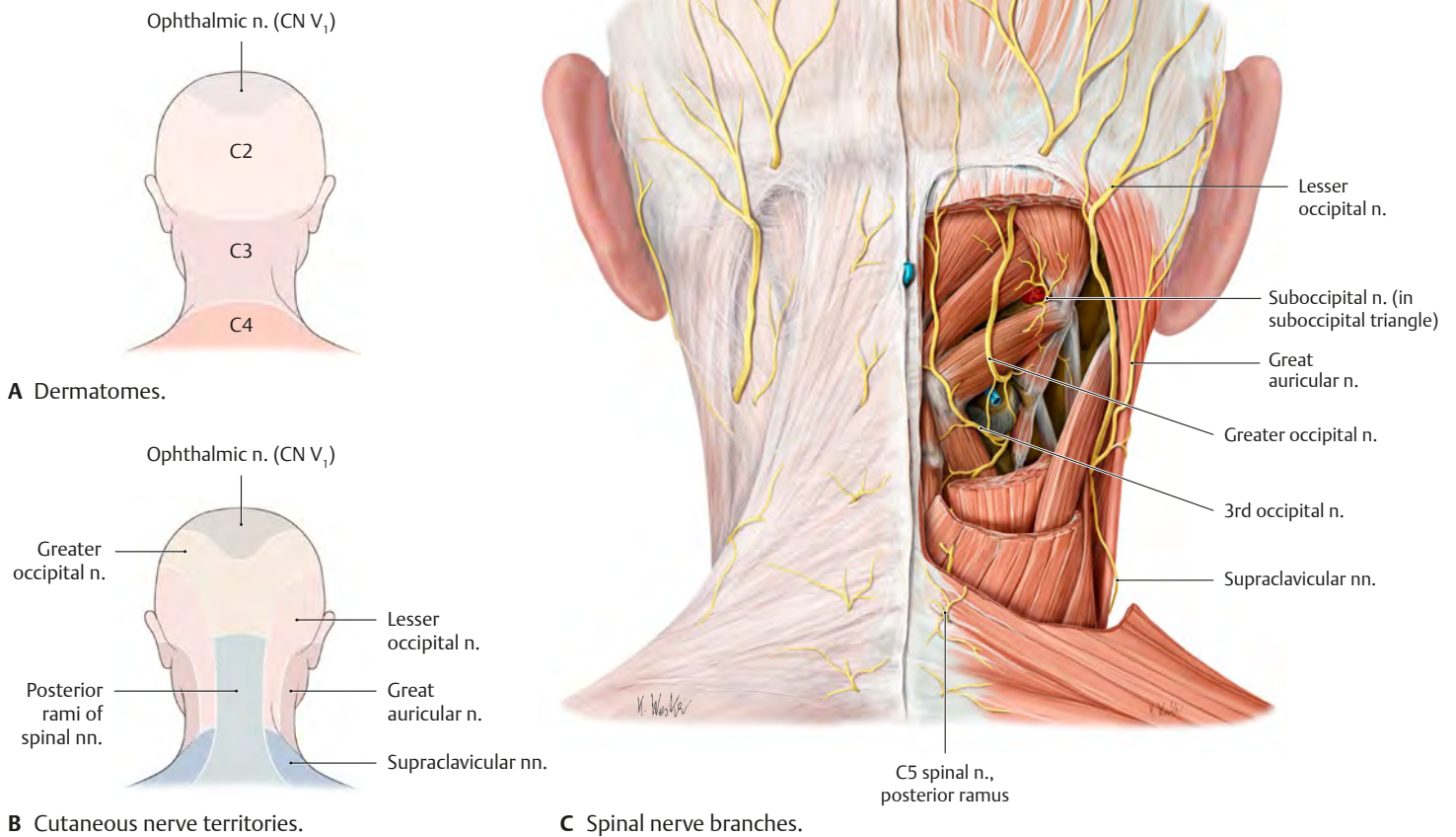
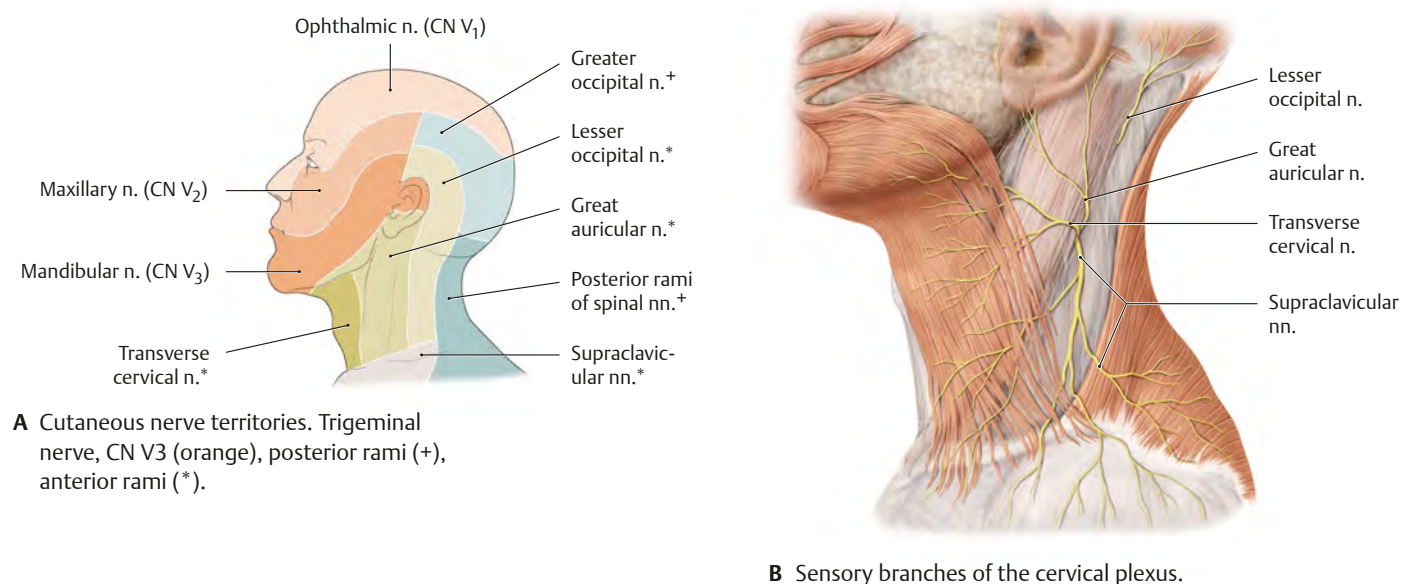
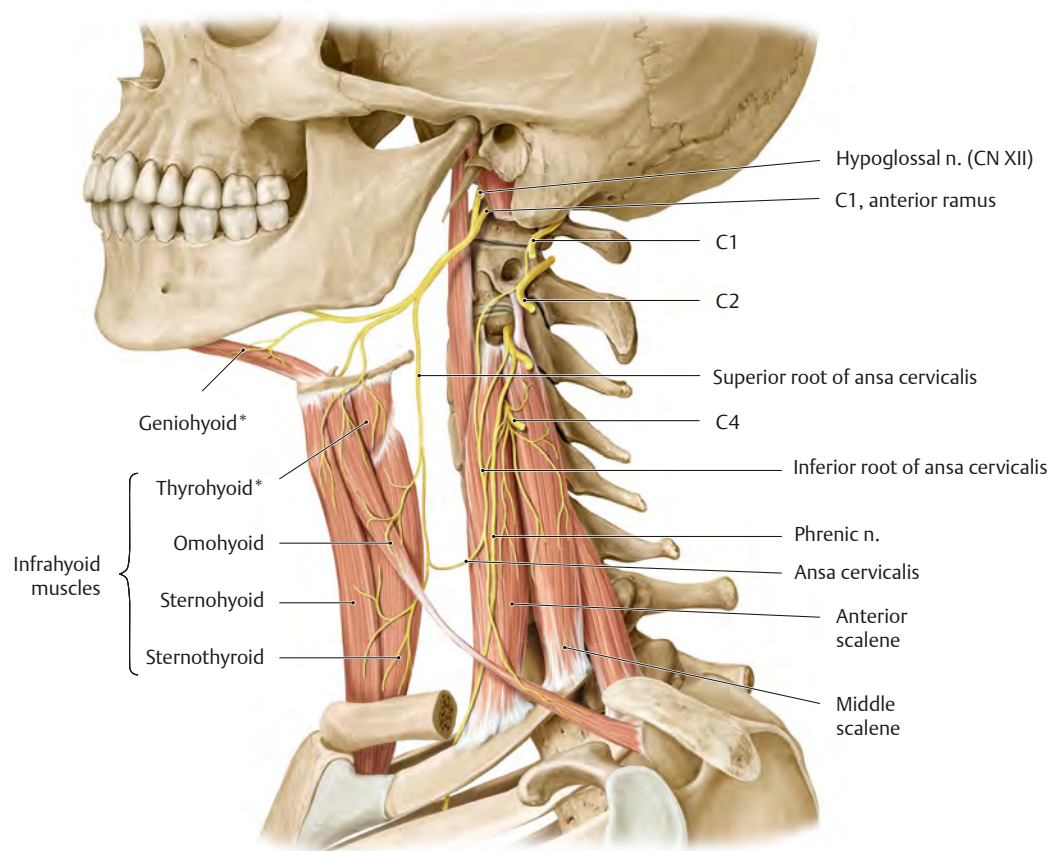


Fig. 37.15 Sensory innervation of the anterolateral neck

Left lateral view.

**Fig. 37.16 Motor innervation of the anterolateral neck**

Left lateral view.



* Innervated by the anterior ramus of C1 (distributed by the hypoglossal n.).

Larynx: Cartilage & Structure

Fig. 37.17 Laryngeal cartilages

Left lateral view. The larynx consists of five laryngeal cartilages: epiglottic, thyroid, cricoid, and the paired arytenoid and corniculate cartilages. They are connected to each other, the trachea, and the hyoid bone by elastic ligaments.

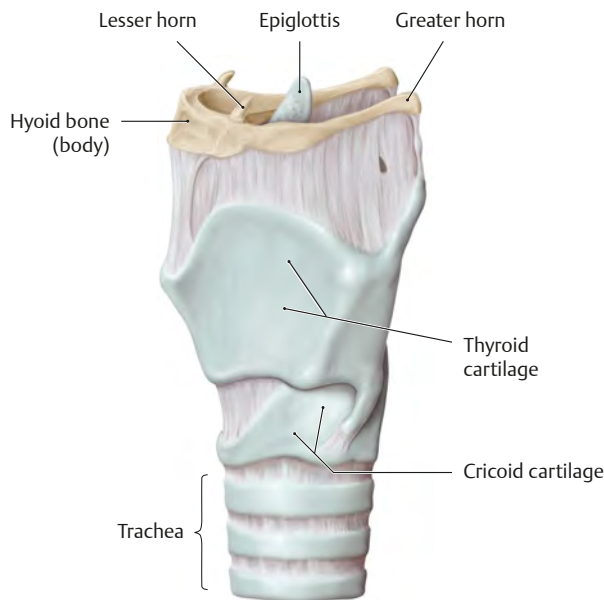


Fig. 37.18 Epiglottic cartilage

The elastic epiglottic cartilage comprises the internal skeleton of the epiglottis, providing resilience to return it to its initial position after swallowing.

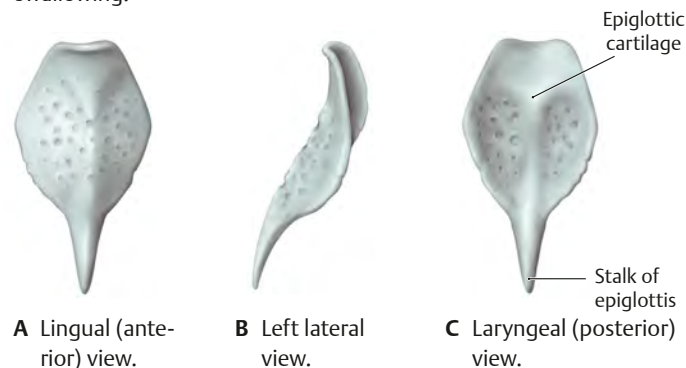


Fig. 37.19 Thyroid cartilage

Left oblique view.

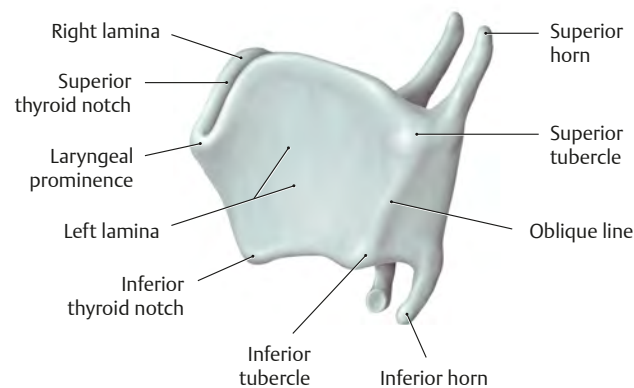


Fig. 37.20 Cricoid cartilage

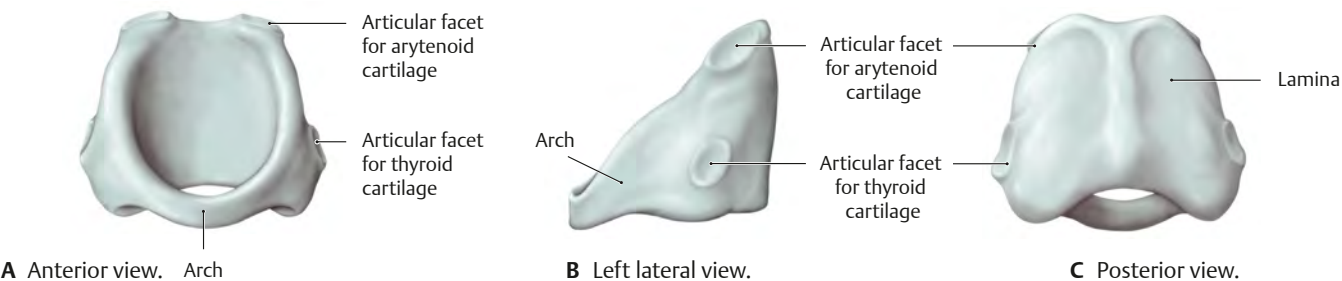


Fig. 37.21 Arytenoid and corniculate cartilages
Right cartilages.

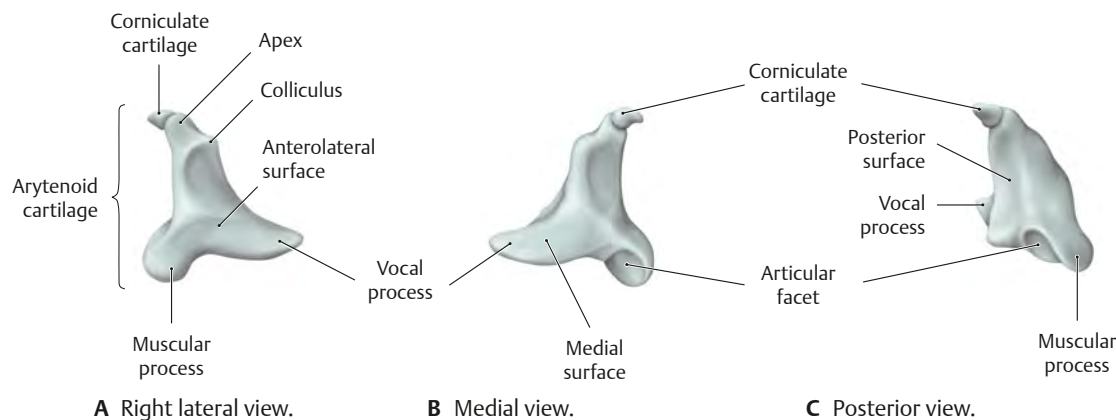
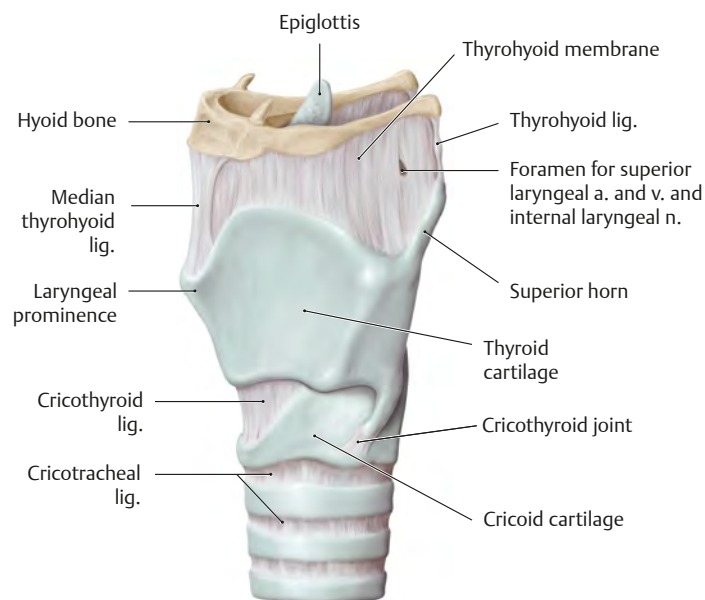
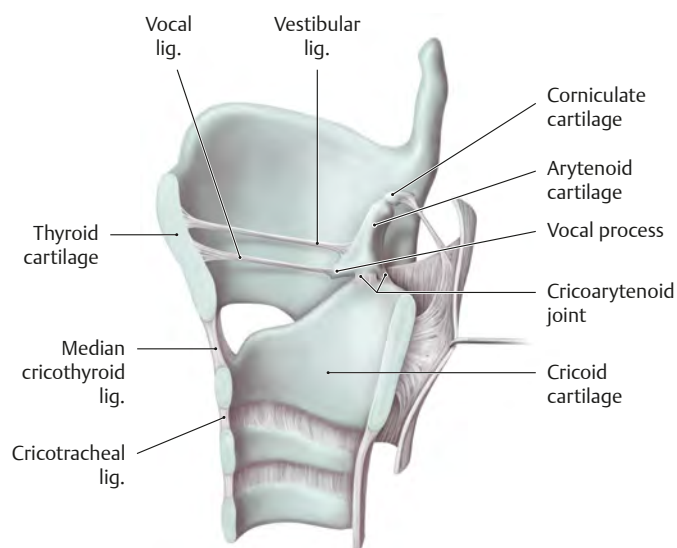


Fig. 37.22 Structure of the larynx

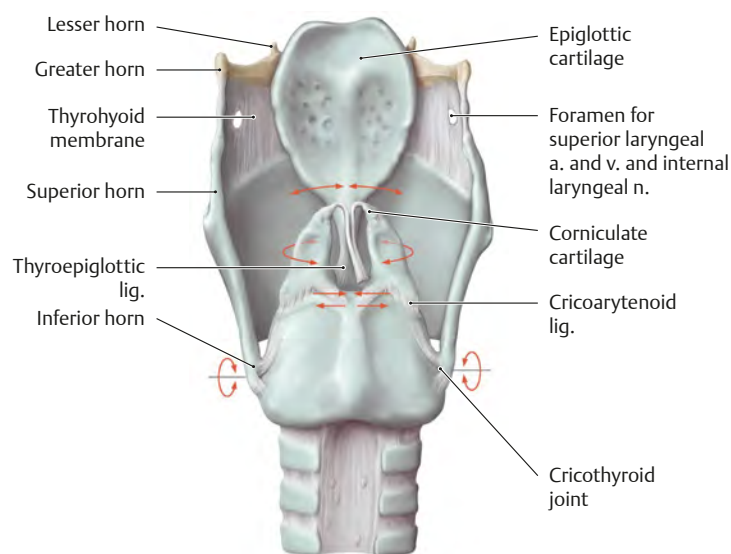
The larynx is suspended from the hyoid bone, primarily by the thyrohyoid membrane. The hyoid bone provides the sites for attachment of the suprahyoid and infrahyoid muscles.



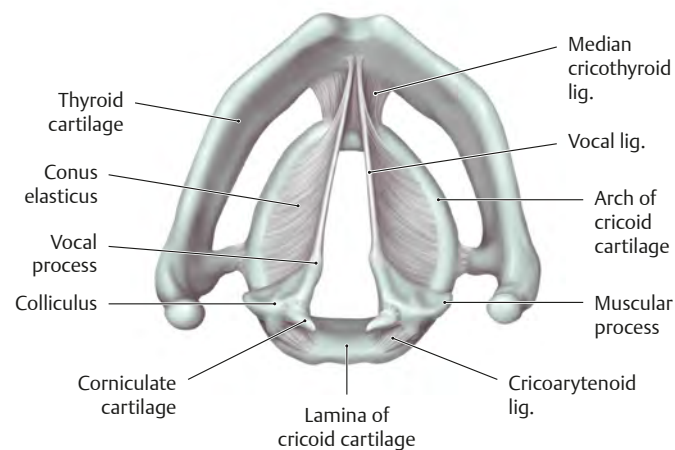
A Left anterior oblique view.



B Sagittal section, viewed from the left medial aspect. The arytenoid cartilage alters the position of the vocal folds during phonation.



C Posterior view. Arrows indicate the directions of movement in the various joints.

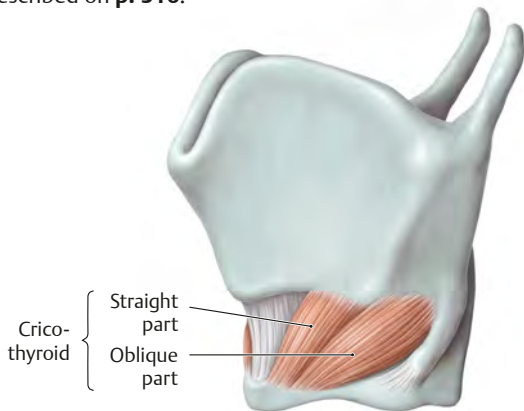


D Superior view.

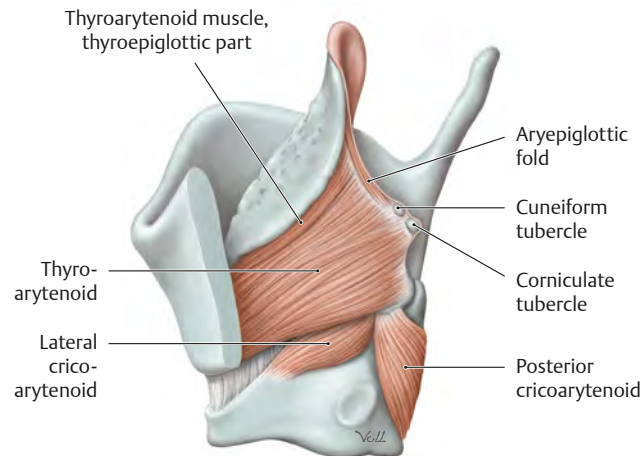
Larynx: Muscles & Levels

Fig. 37.23 Laryngeal muscles

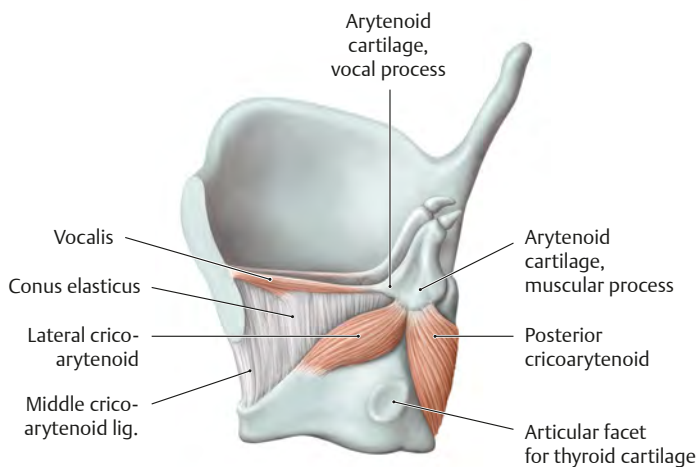
The laryngeal muscles move the laryngeal cartilages relative to one another, affecting the tension and/or position of the vocal folds. Muscles that move the larynx as a whole (infra- and suprahyoid muscles) are described on p. 516.



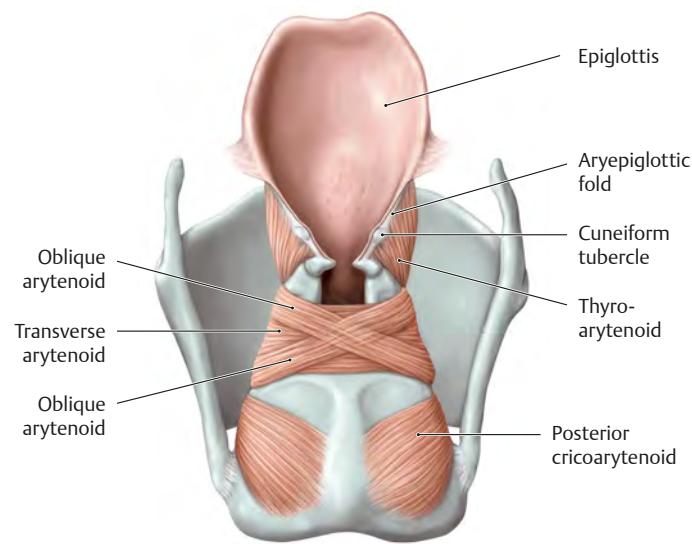
A Intrinsic laryngeal muscles, left lateral oblique view.



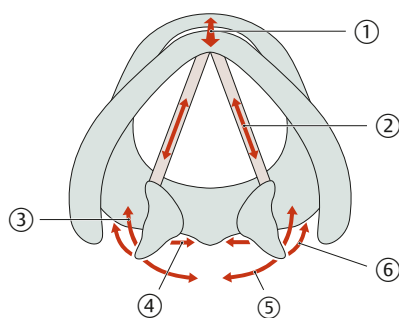
B Intrinsic laryngeal muscles, left lateral view. *Removed:* Thyroid cartilage (left half). *Revealed:* Epiglottis and thyroarytenoid muscle.



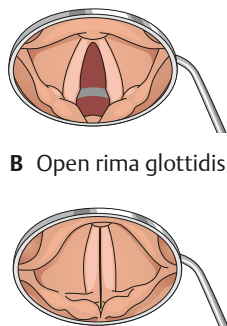
C Left lateral view with the epiglottis removed.



D Posterior view.



A Laryngeal muscles, superior view.



B Open rima glottidis.

C Closed rima glottidis.

Table 37.9 Actions of the laryngeal muscles

Muscle	Action	Effect on rima glottidis
① Cricothyroid m.*	Tightens the vocal folds	None
② Vocalis m.		
③ Thyroarytenoid m.	Adducts the vocal folds	Closes
④ Transverse arytenoid m.		
⑤ Posterior cricoarytenoid m.	Abducts the vocal folds	Opens
⑥ Lateral cricoarytenoid m.	Adducts the vocal folds	Closes

* The cricothyroid is innervated by the external laryngeal n. All other intrinsic laryngeal mm. are innervated by the recurrent laryngeal n.

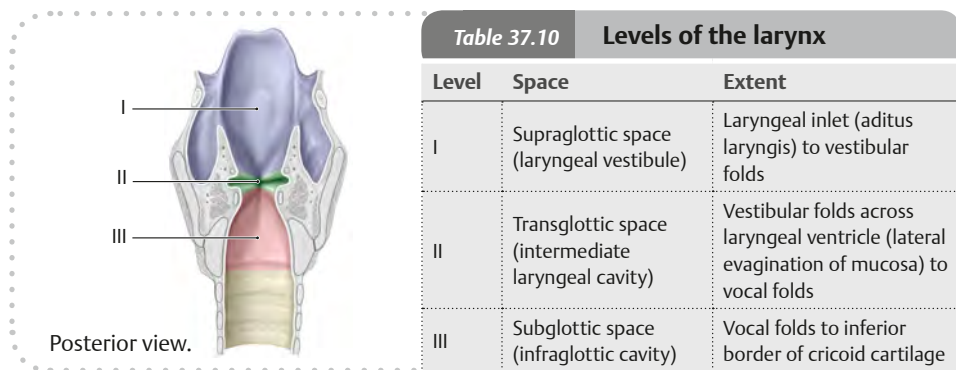


Fig. 37.24 Cavity of the larynx

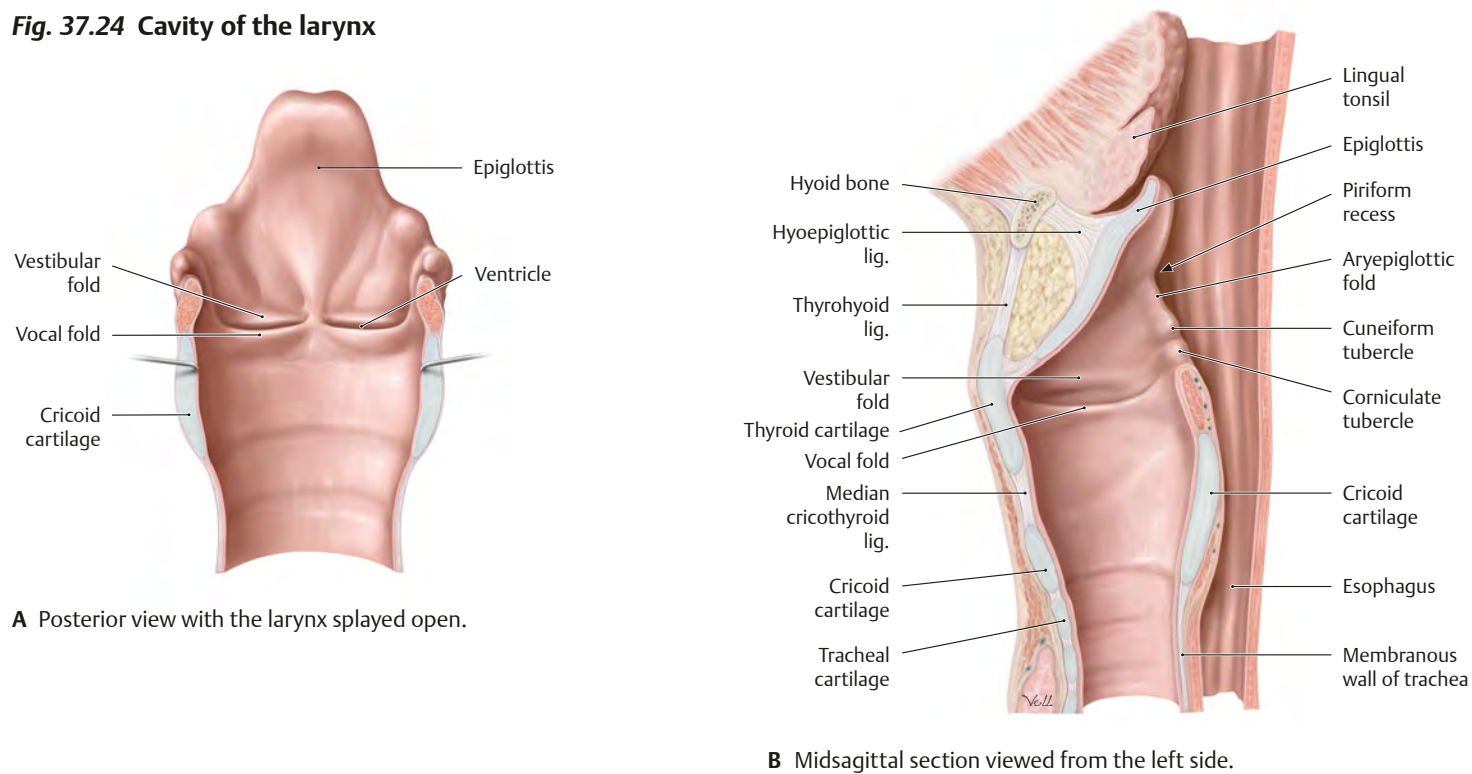
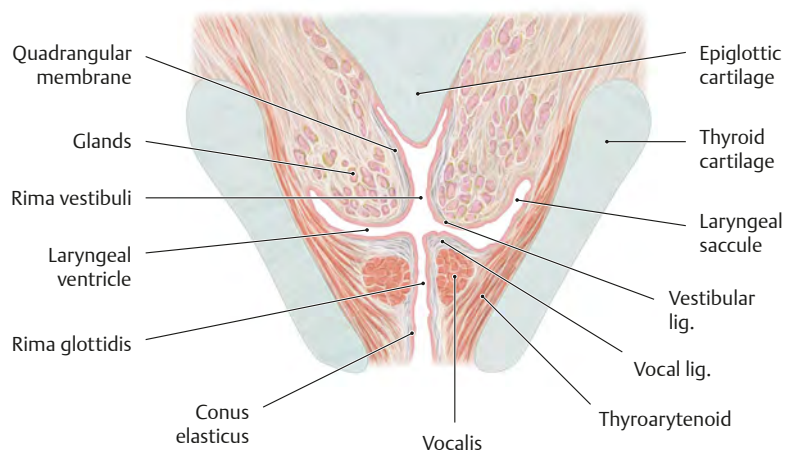


Fig. 37.25 Vestibular and vocal folds

Coronal section, superior view.



Neurovasculature of the Larynx, Thyroid & Parathyroids

Fig. 37.26 Thyroid and parathyroid glands

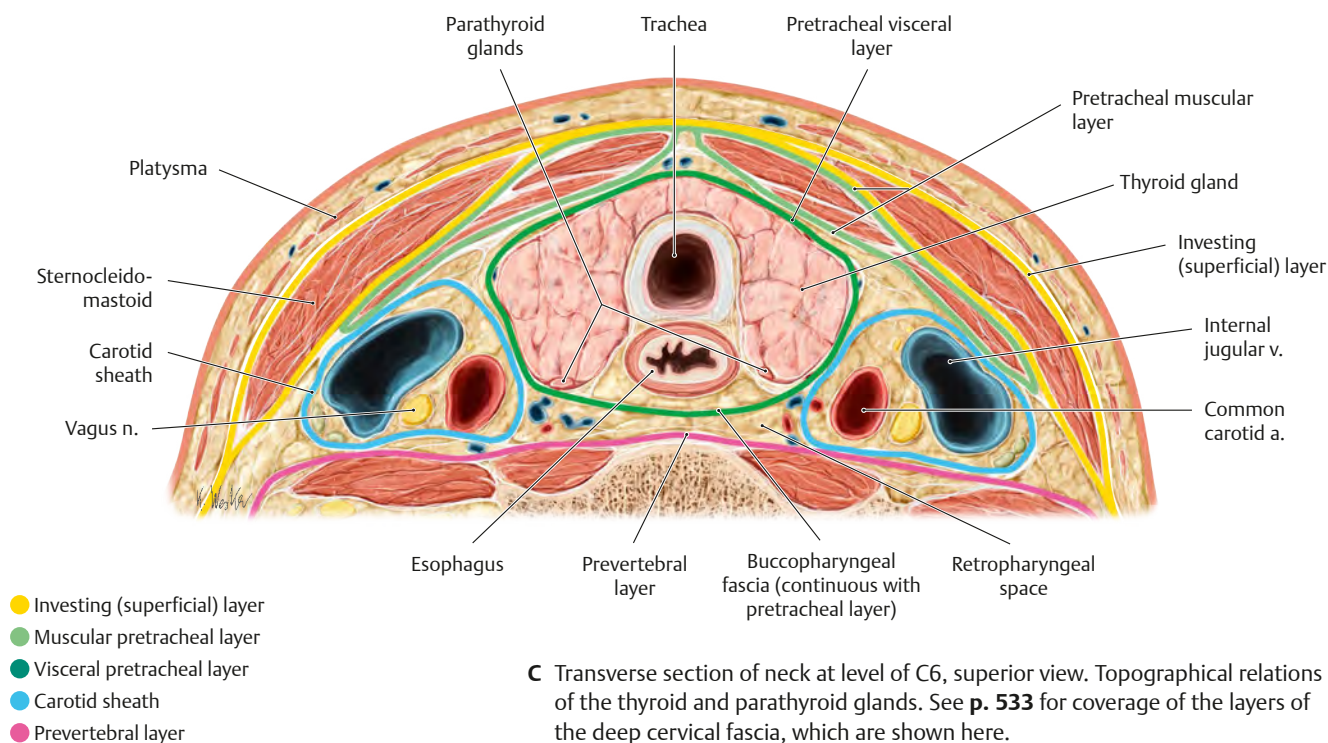
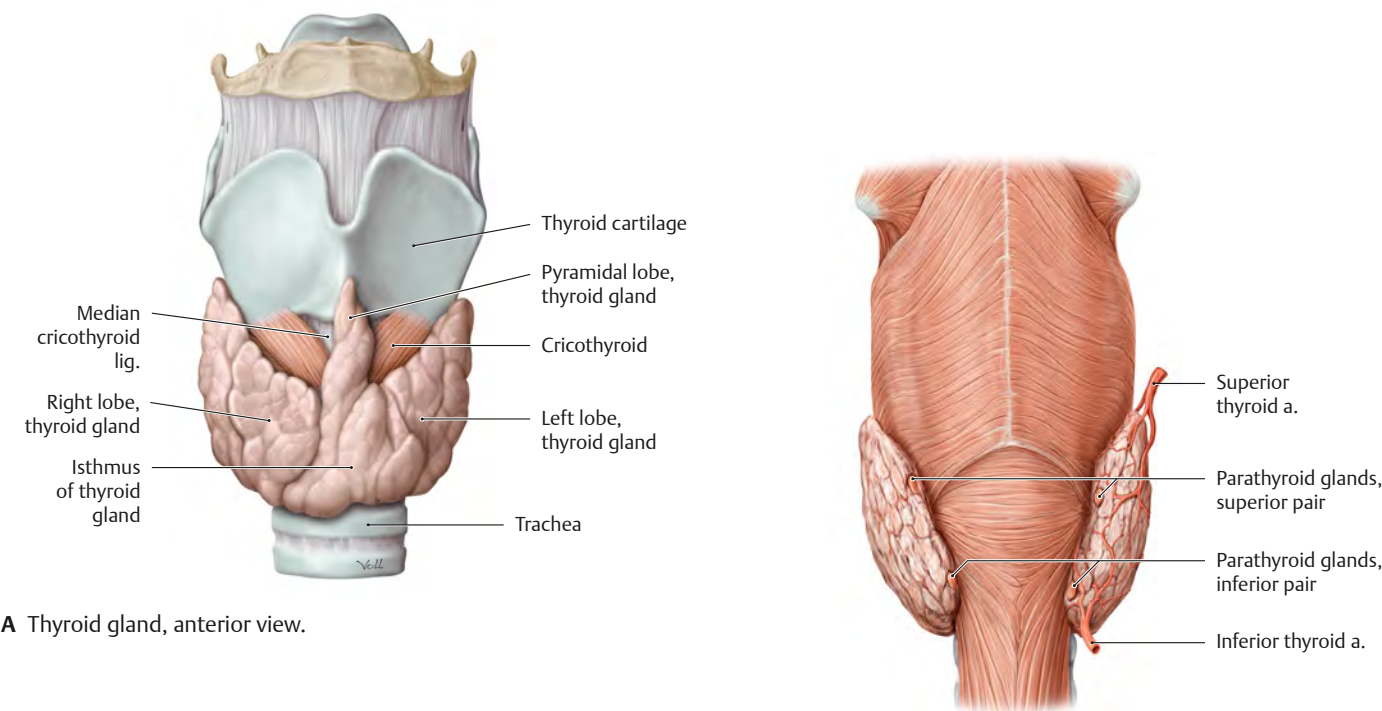
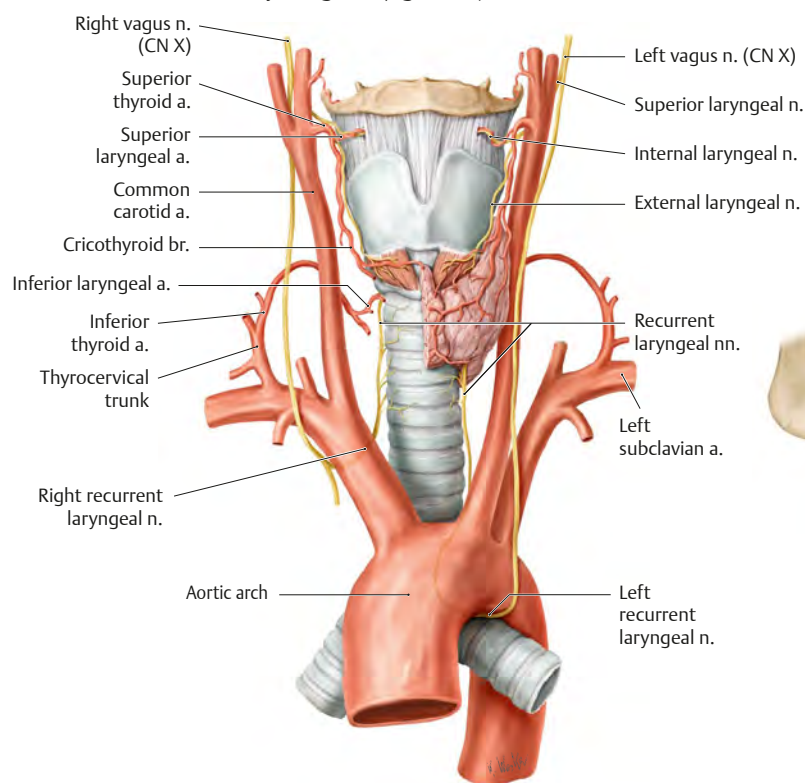
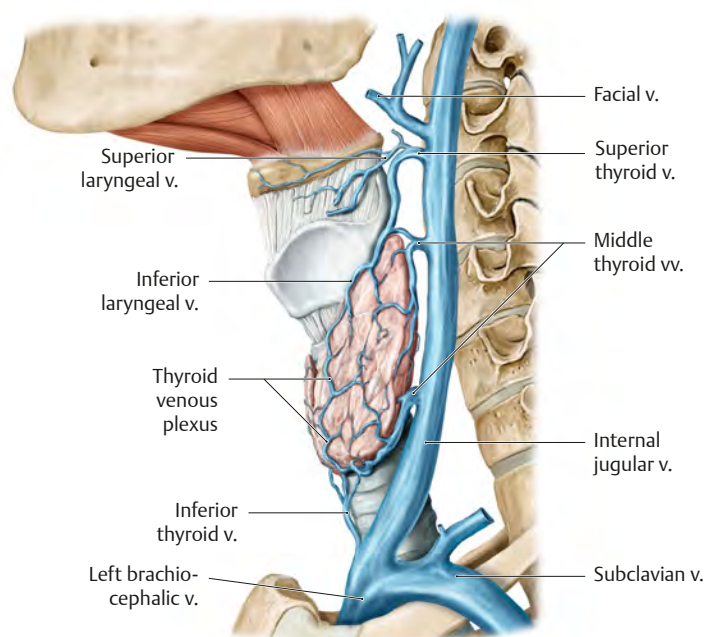
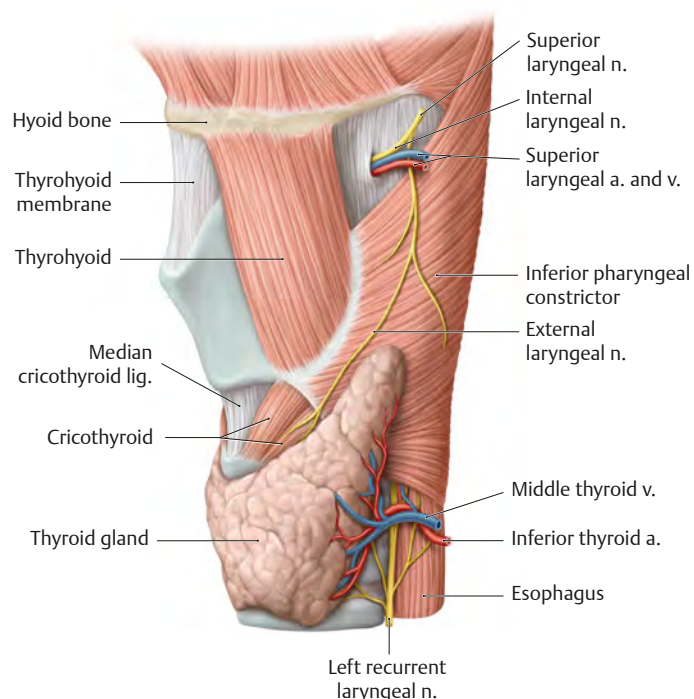
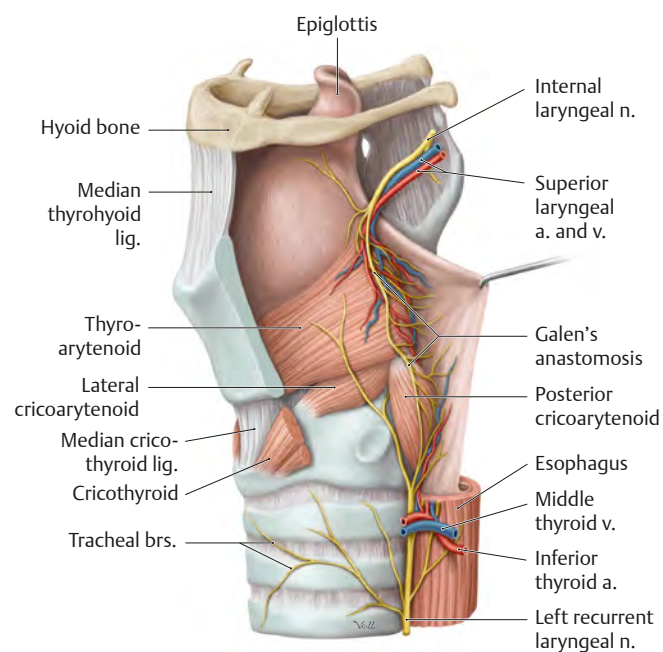


Fig. 37.27 Arteries and nerves of the larynxAnterior view. *Removed:* Thyroid gland (right half).**Fig. 37.28 Veins of the larynx**Left lateral view. *Note:* The inferior thyroid vein generally drains into the left brachiocephalic vein.**Fig. 37.29 Neurovasculature of the larynx**

Left lateral view.

**A** Superficial layer.**B** Deep layer. *Removed:* Cricothyroid muscle and left lamina of thyroid cartilage. *Retracted:* Pharyngeal mucosa.

Topography of the Neck: Regions & Fascia

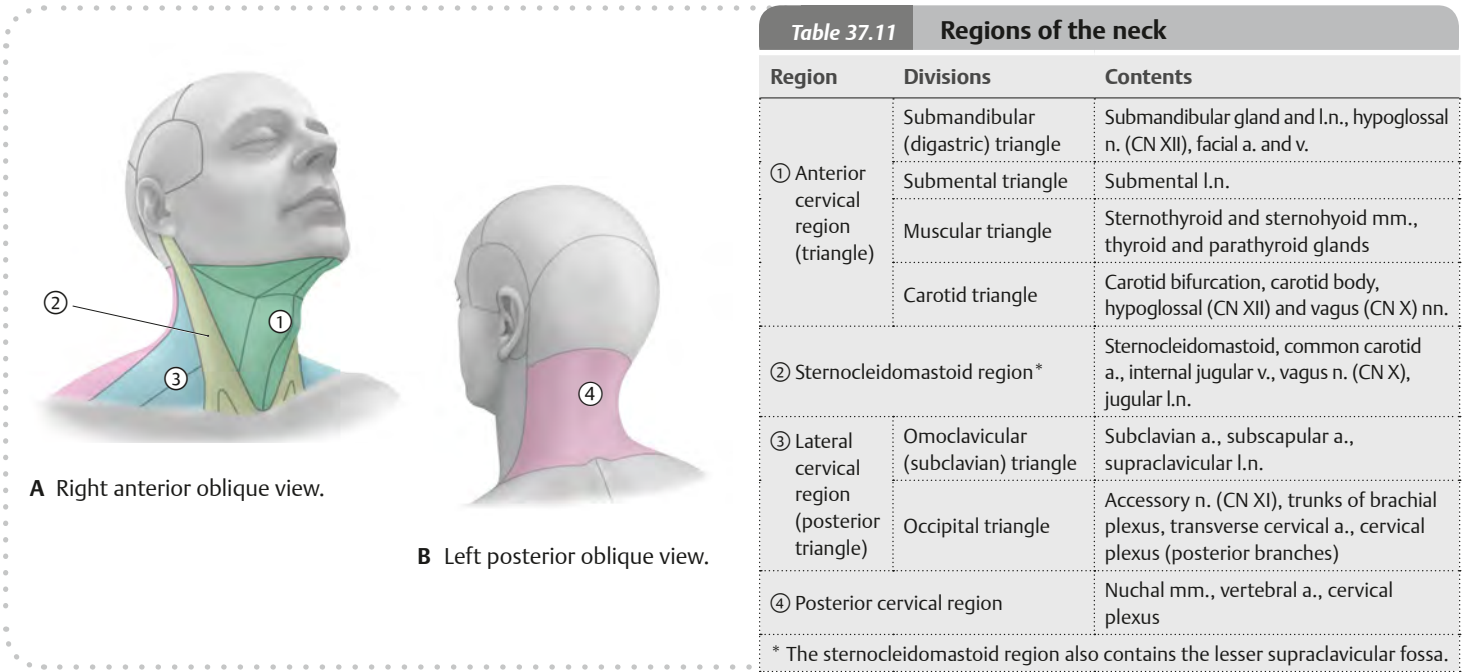


Fig. 37.30 Cervical regions

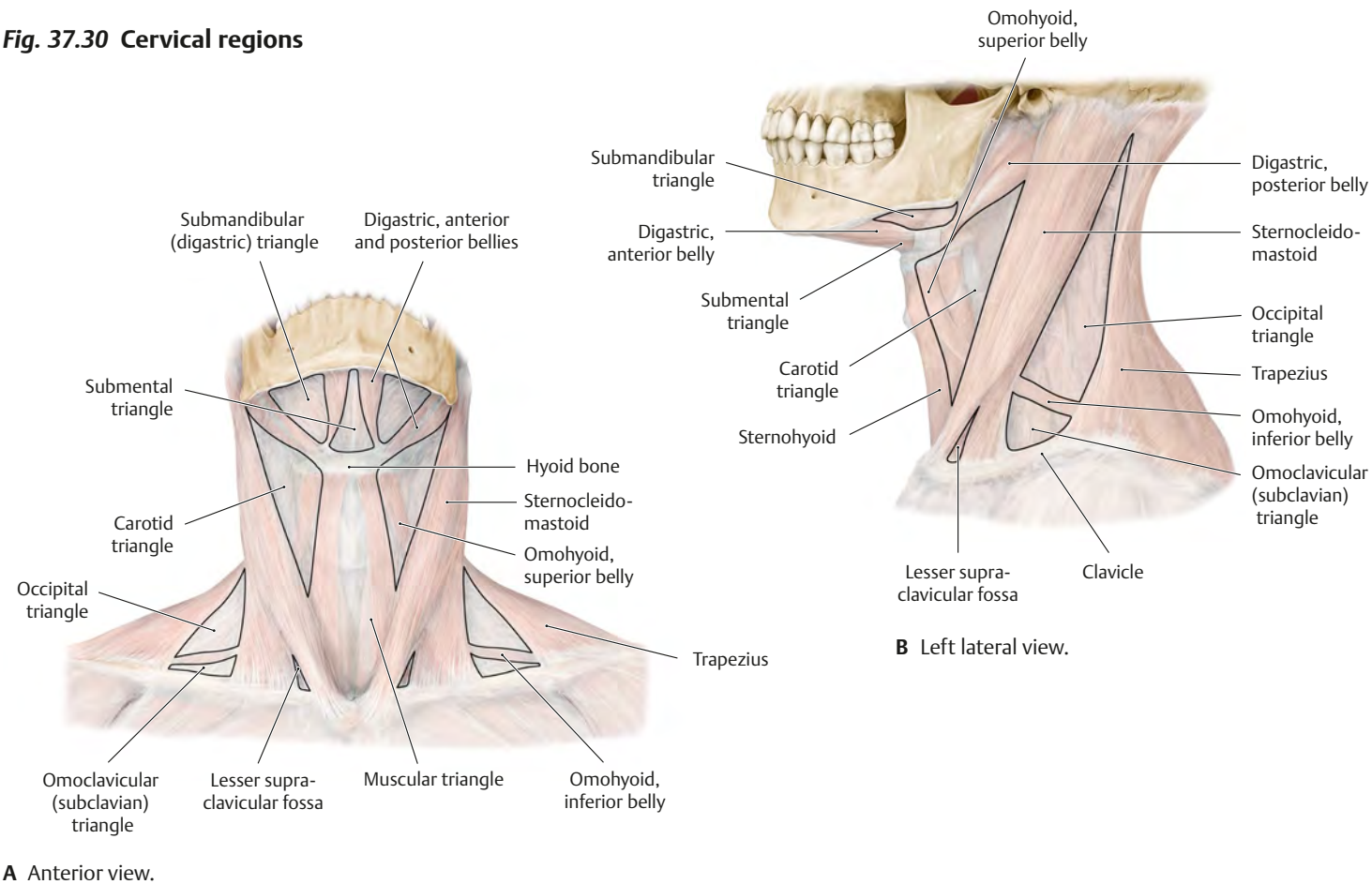
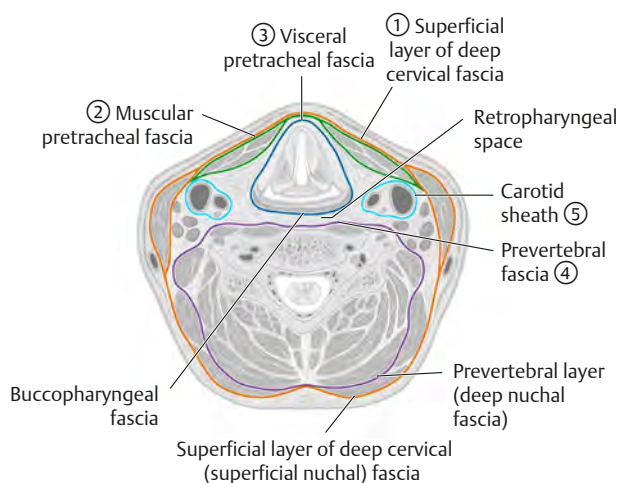


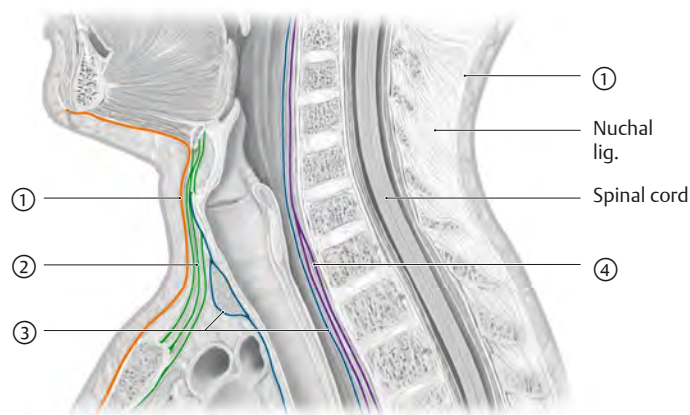
Table 37.12 Deep cervical fascia

The deep cervical fascia is divided into four layers that enclose the structures of the neck.

Layer	Type of fascia	Description
① Investing (superficial) layer	Muscular	Envelopes entire neck; splits to enclose sternocleidomastoid and trapezius muscles
Pretracheal layer	② Muscular	Encloses infrahyoid muscles
	③ Visceral	Surrounds thyroid gland, larynx, trachea, pharynx, and esophagus
④ Prevertebral layer	Muscular	Surrounds cervical vertebral column and associated muscles
⑤ Carotid sheath	Neurovascular	Encloses common carotid artery, internal jugular vein, and vagus nerve



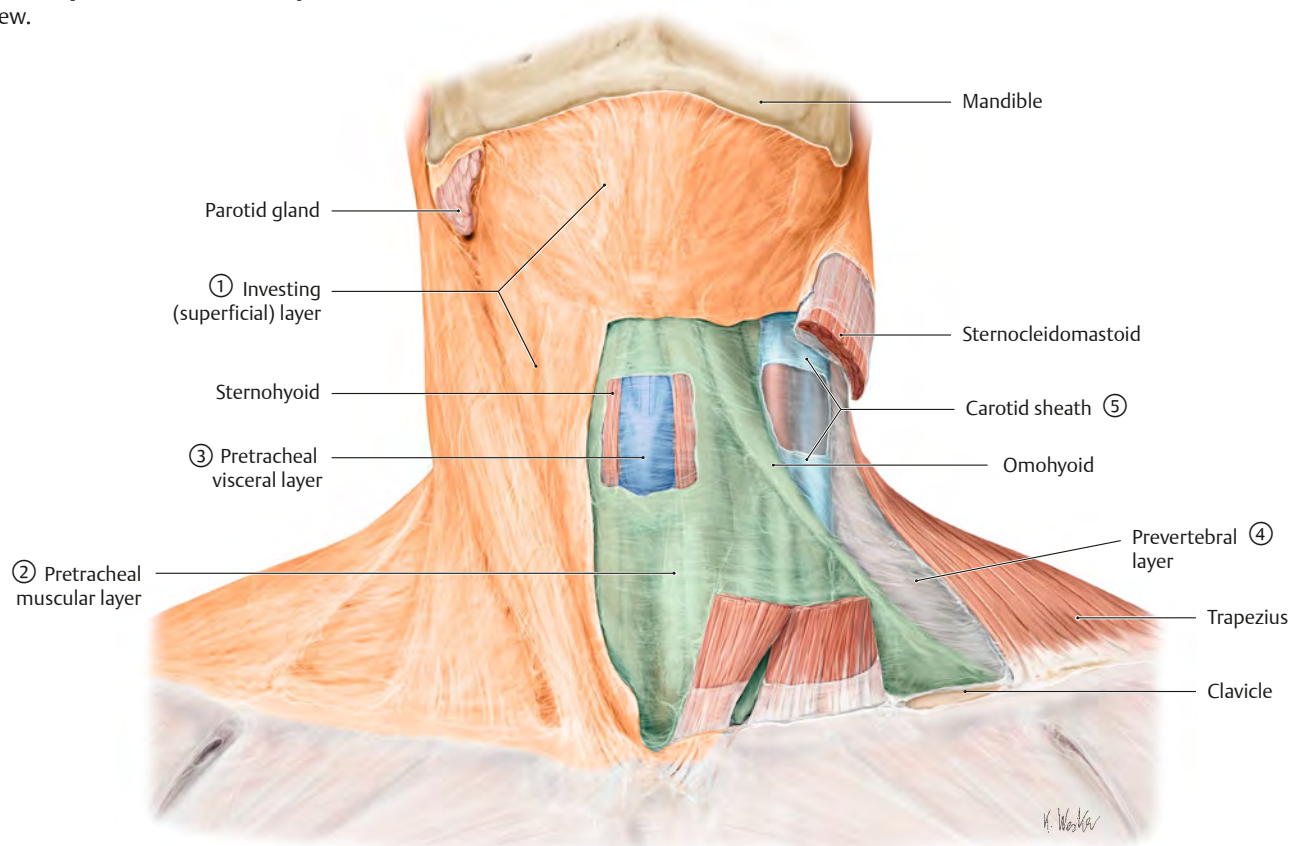
A Transverse section at level of C5 vertebra.



B Midsagittal section, left lateral view.

Fig. 37.31 Deep cervical fascial layers

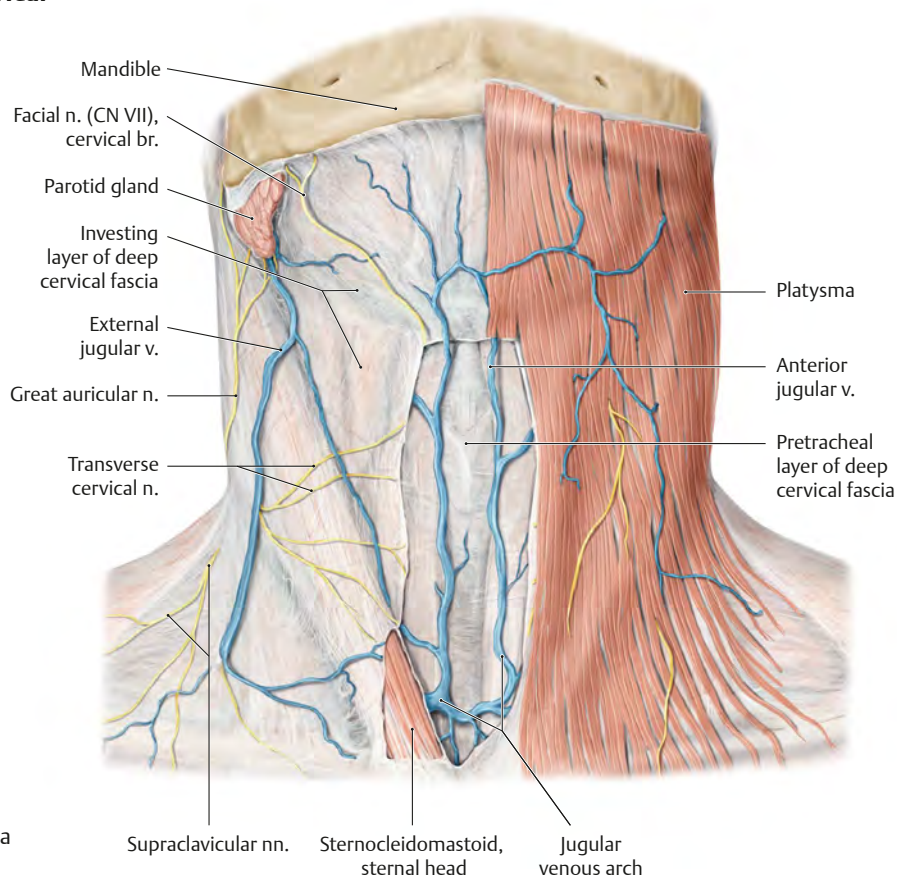
Anterior view.



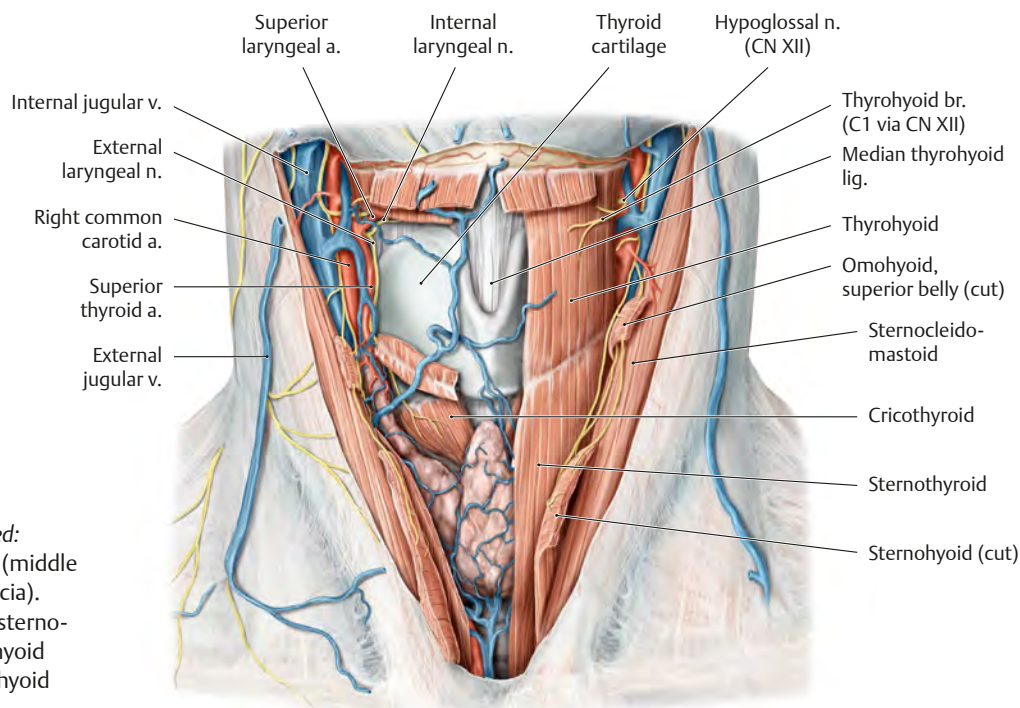
Topography of the Anterior Cervical Region

Fig. 37.32 Anterior cervical triangle

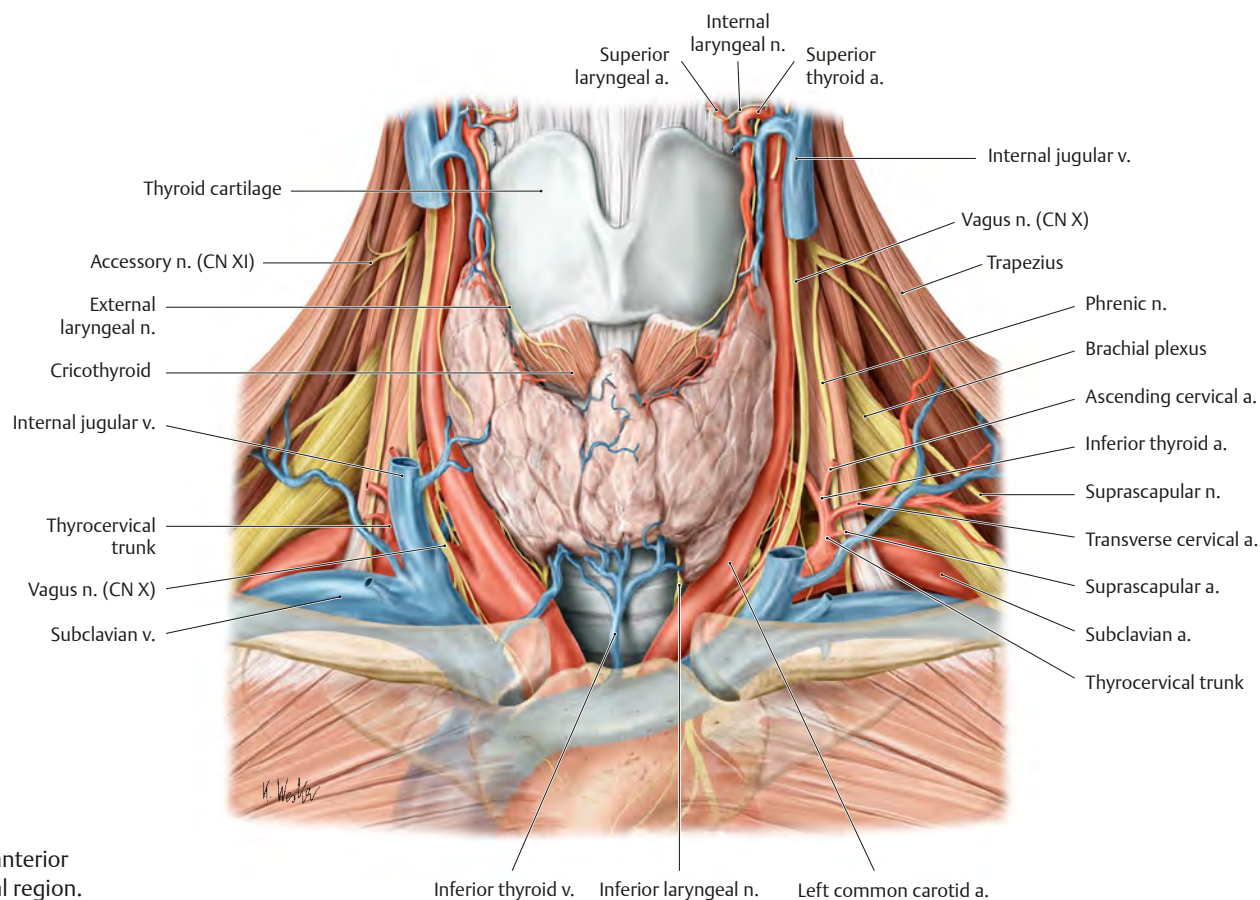
Anterior view.



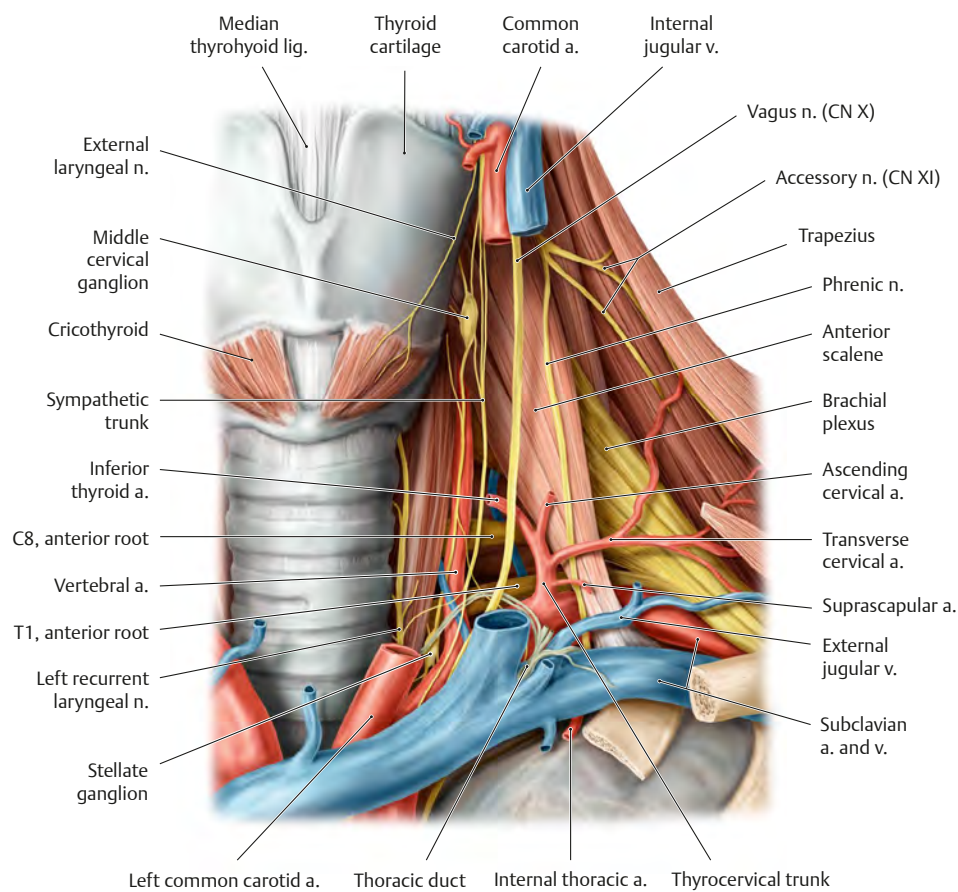
A Superficial layer. *Removed:* Subcutaneous platysma (right side) and investing layer of deep cervical fascia (center).



B Deep layer. *Removed:* Pretracheal lamina (middle layer of cervical fascia). *Cuts:* Sternohyoid, sternothyroid, and thyrohyoid (right side); sternohyoid (left side).



C Deep anterior cervical region.



D Root of the neck.

Topography of the Anterior & Lateral Cervical Regions

Fig. 37.33 Deep anterior cervical region

The deep midline viscera of the anterior cervical region are the larynx and thyroid gland. The two lateral neurovascular pathways primarily supply these organs.

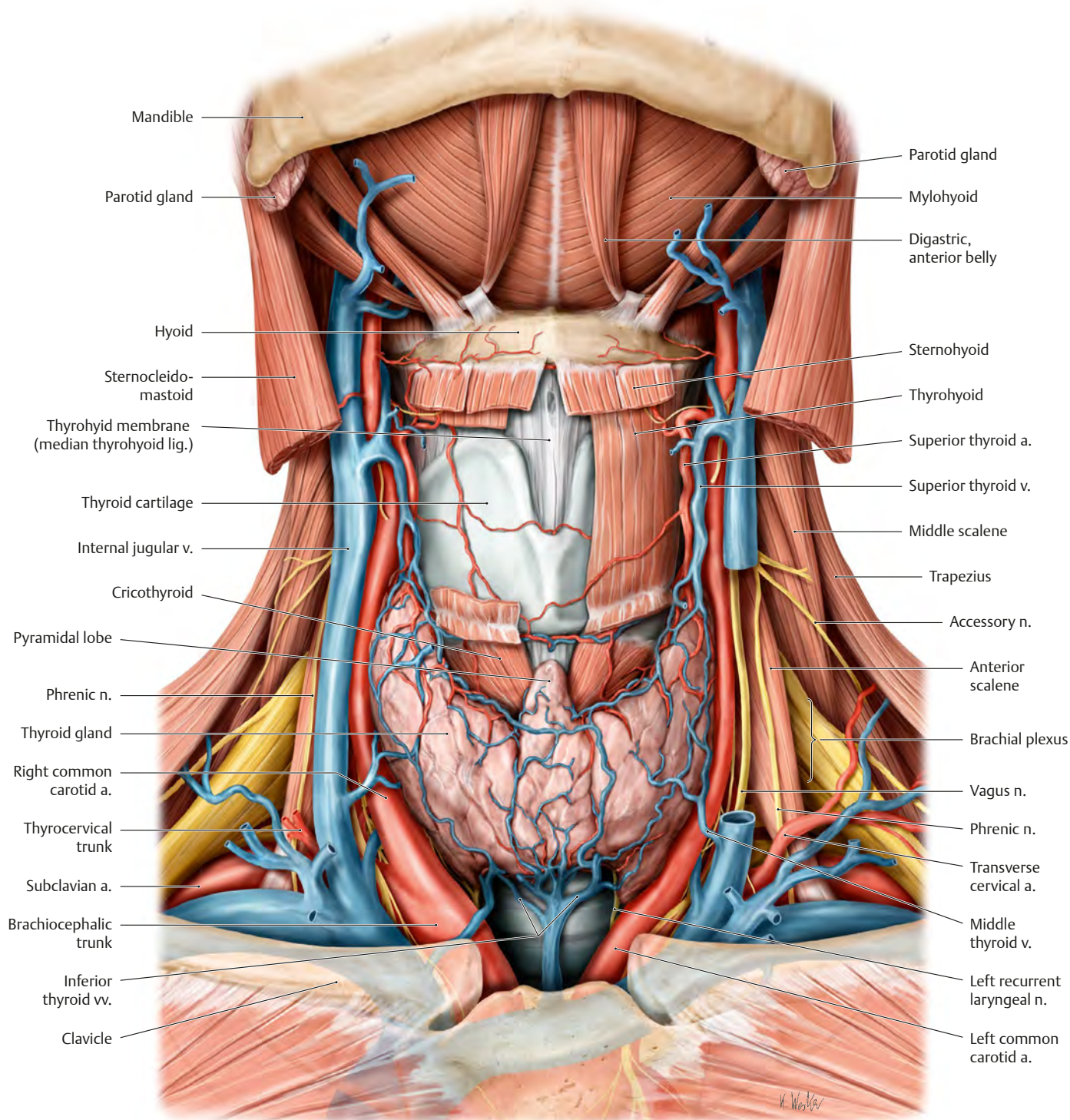
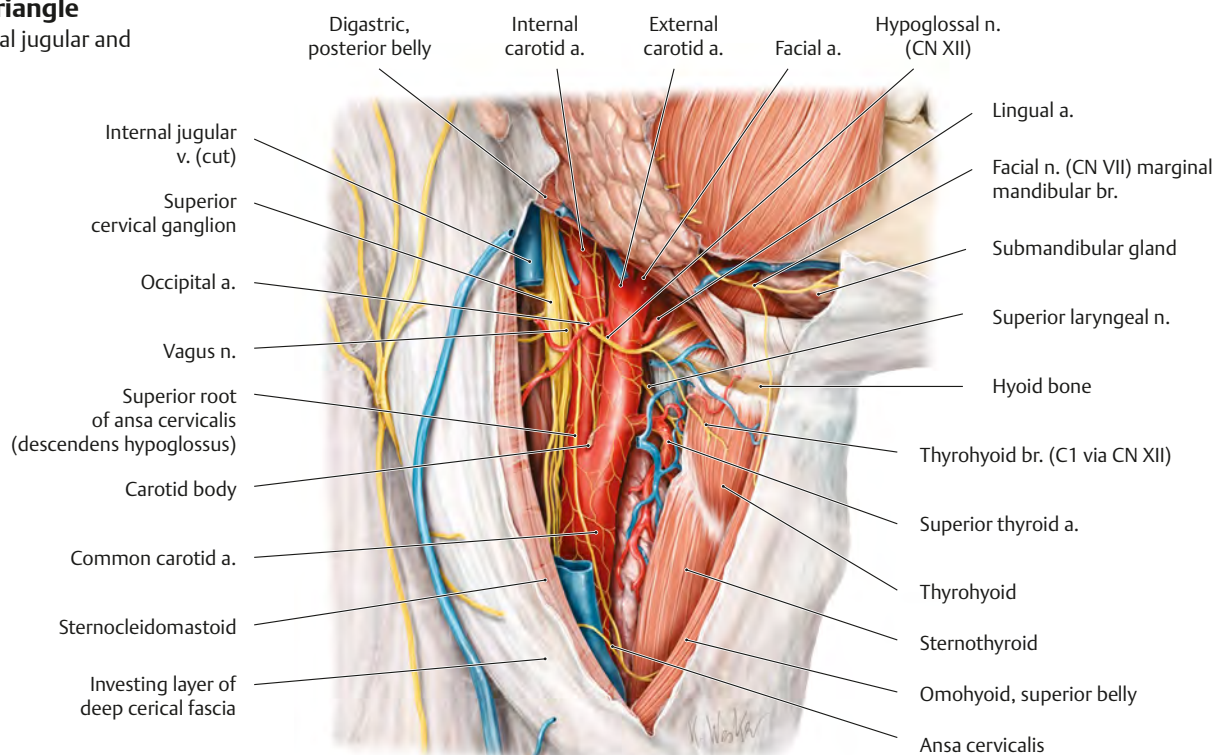
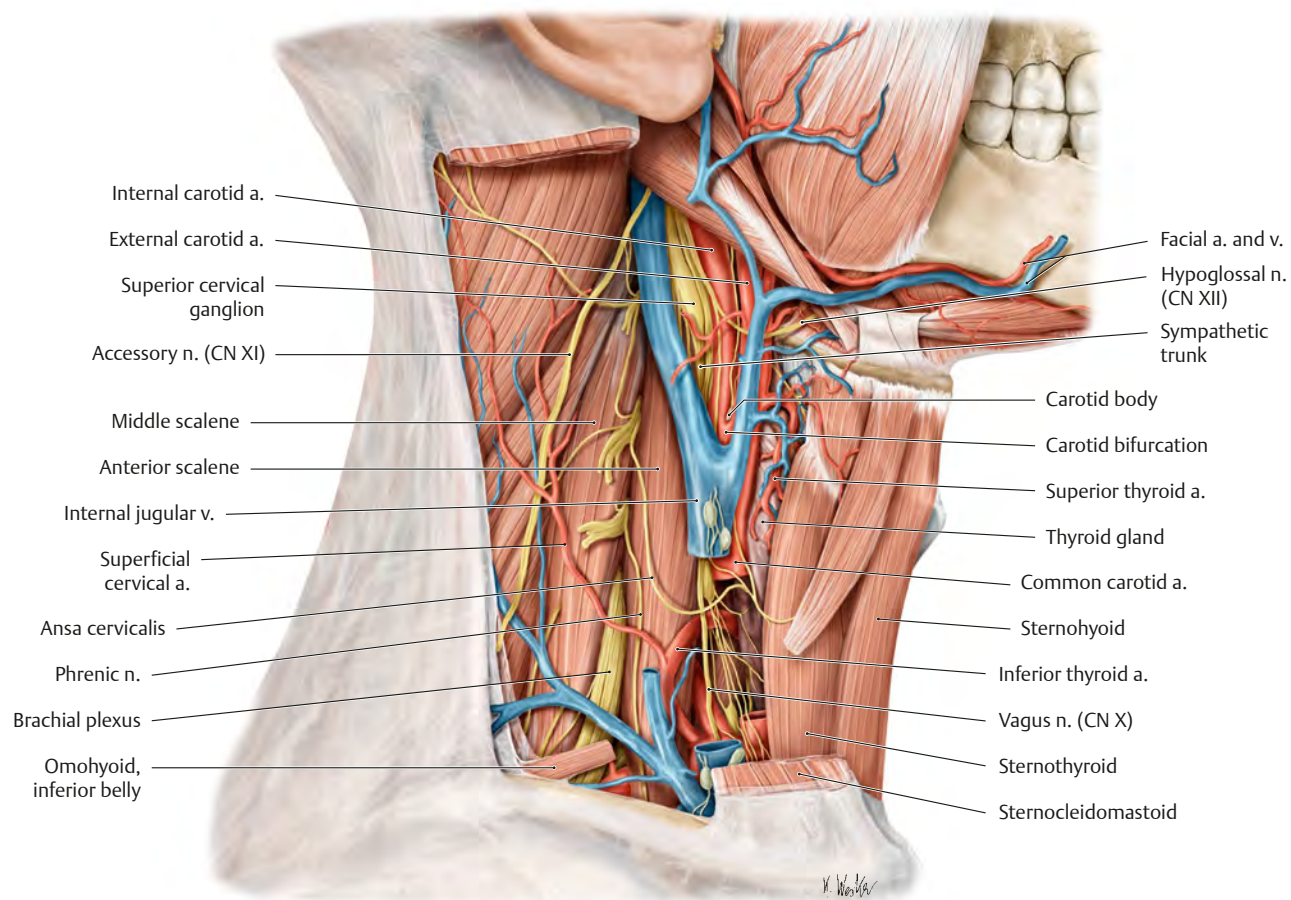


Fig. 37.34 Carotid triangle

Right lateral view. Internal jugular and facial veins removed.

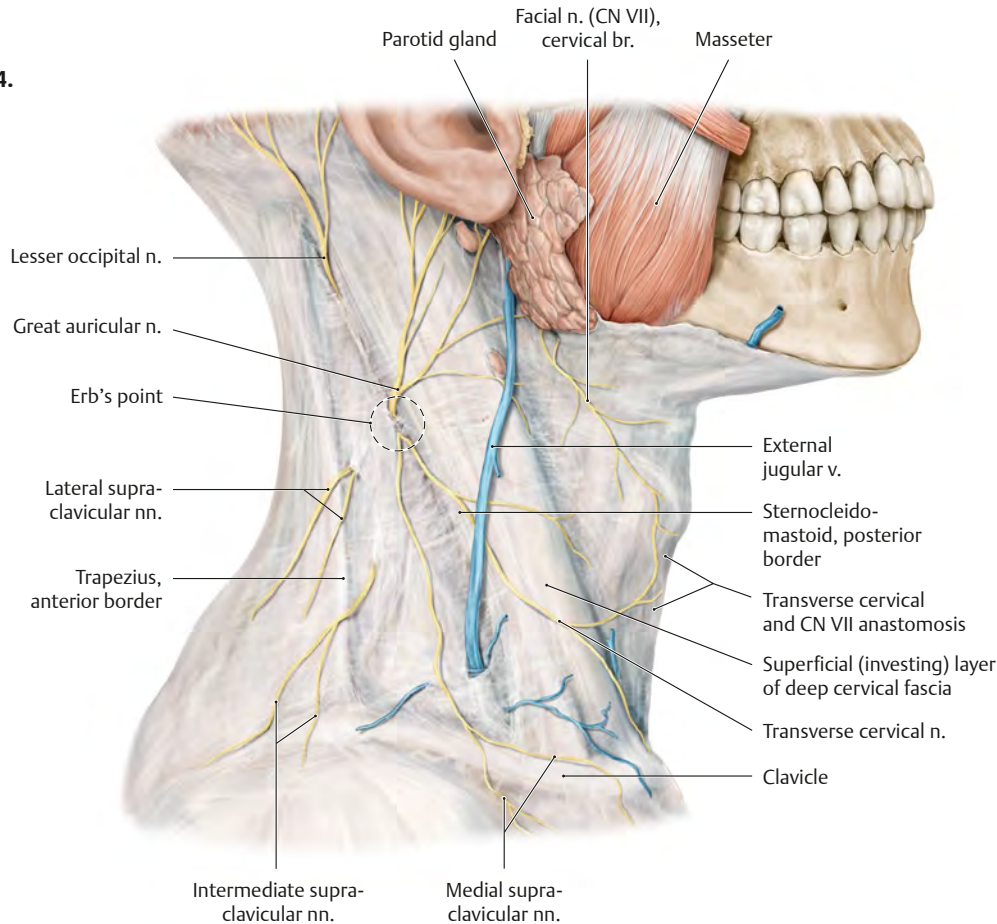
**Fig. 37.35 Deep lateral cervical region**

Right lateral view with sternocleidomastoid windowed.

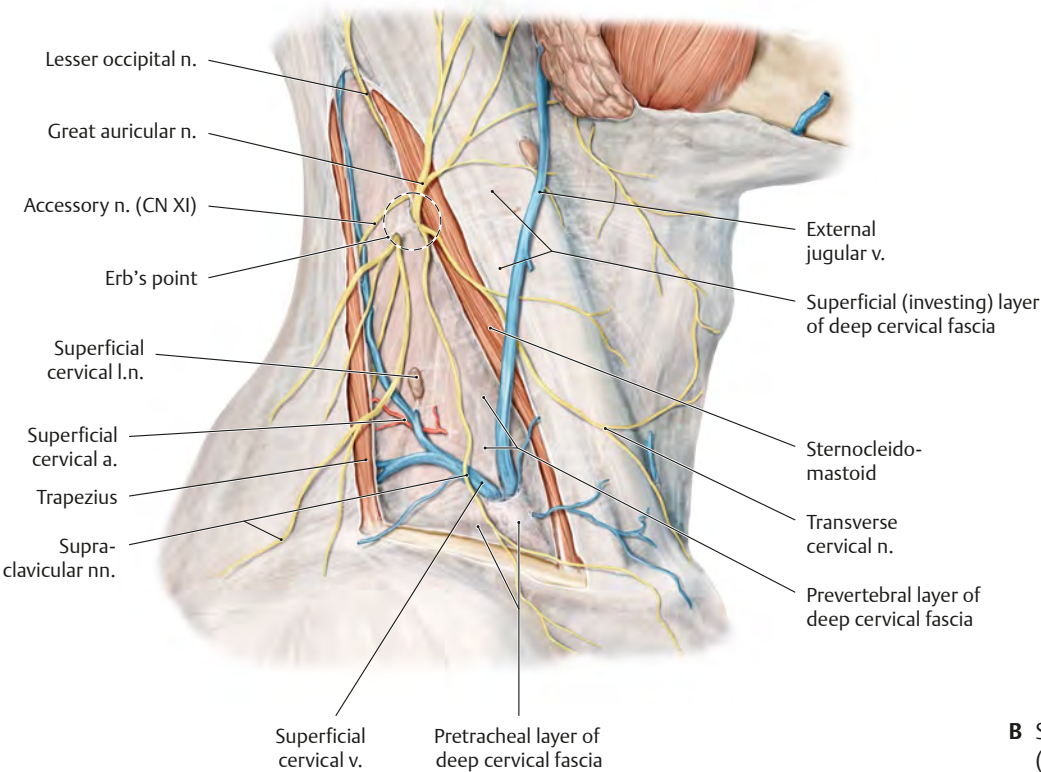


Topography of the Lateral Cervical Region

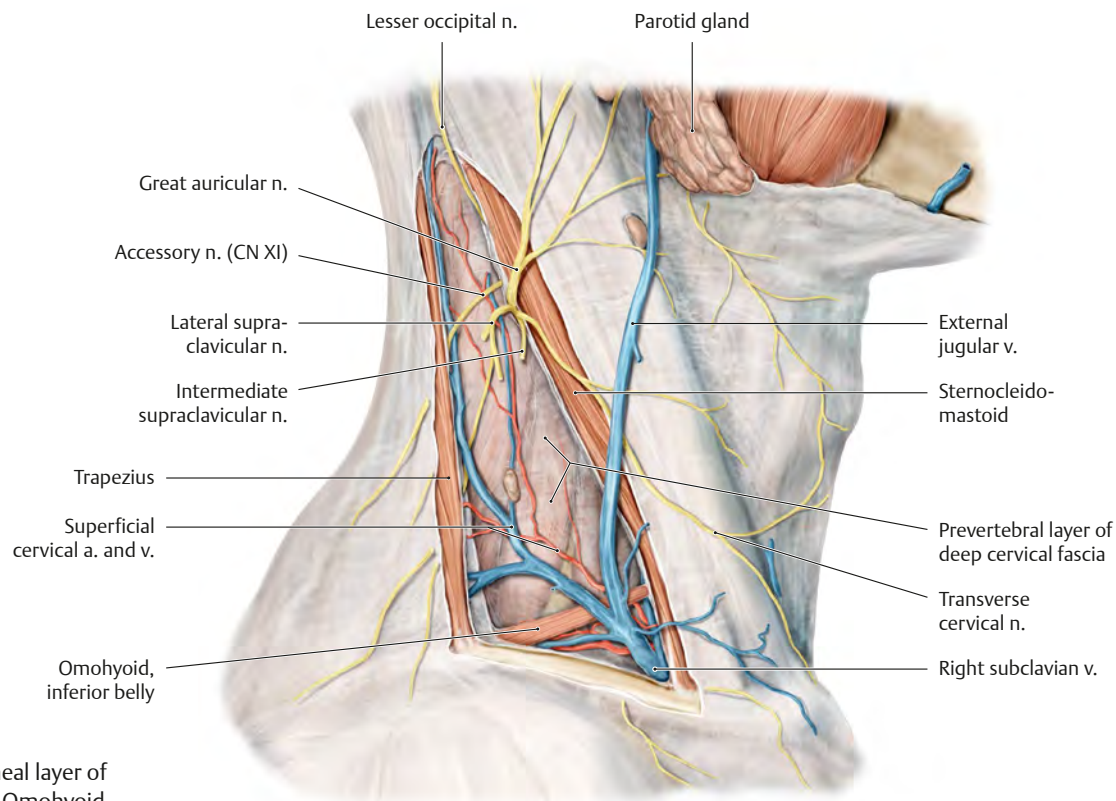
Fig. 37.36 Lateral cervical region
 Right lateral view. The contents of the deep lateral cervical region are found in Fig. 37.34.



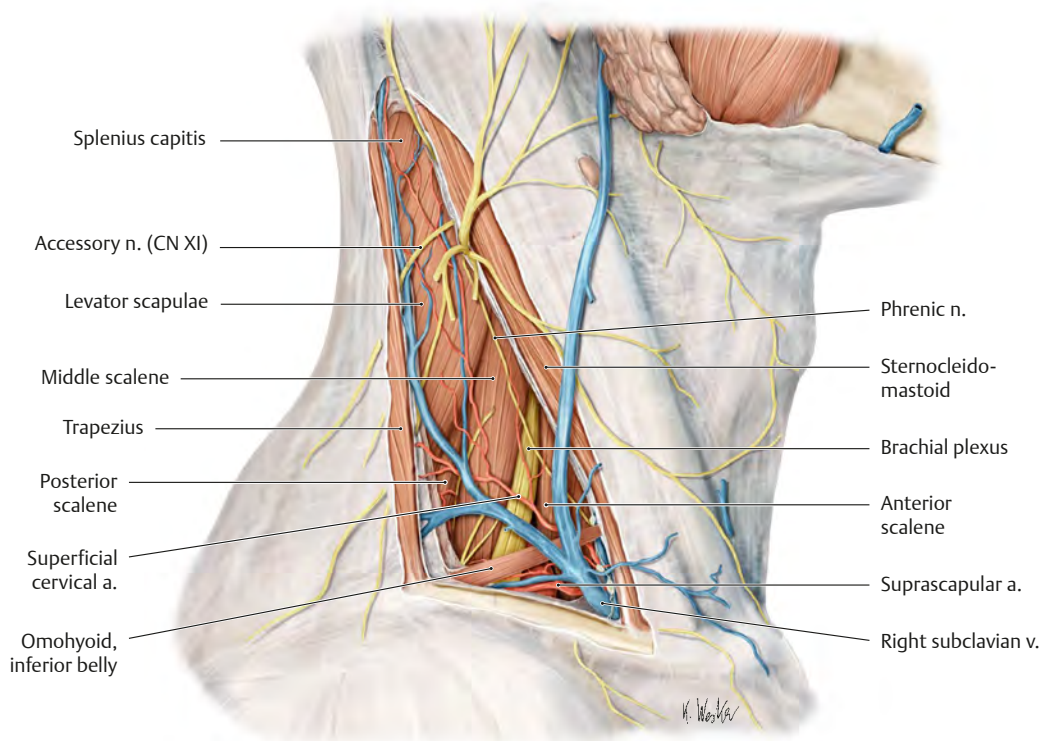
A Subcutaneous layer.



B Subfascial layer. *Removed:* Superficial (investing) layer of deep cervical fascia.



C Deep layer. *Removed:* Pretracheal layer of deep cervical fascia. *Revealed:* Omohyoid, omoclavicular (subclavian) triangle.



D Deepest layer. *Removed:* Prevertebral layer of deep cervical fascia. *Revealed:* Muscular floor of posterior triangle, brachial plexus, and phrenic nerve.

Topography of the Posterior Cervical Region

Fig. 37.37 Occipital and posterior cervical regions

Posterior view. Subcutaneous layer (left), subfascial layer (right). The occiput is technically a region of the head, but it is included here due to the continuity of the vessels and nerves from the neck. *Removed on right side:* Investing layer of deep cervical fascia.

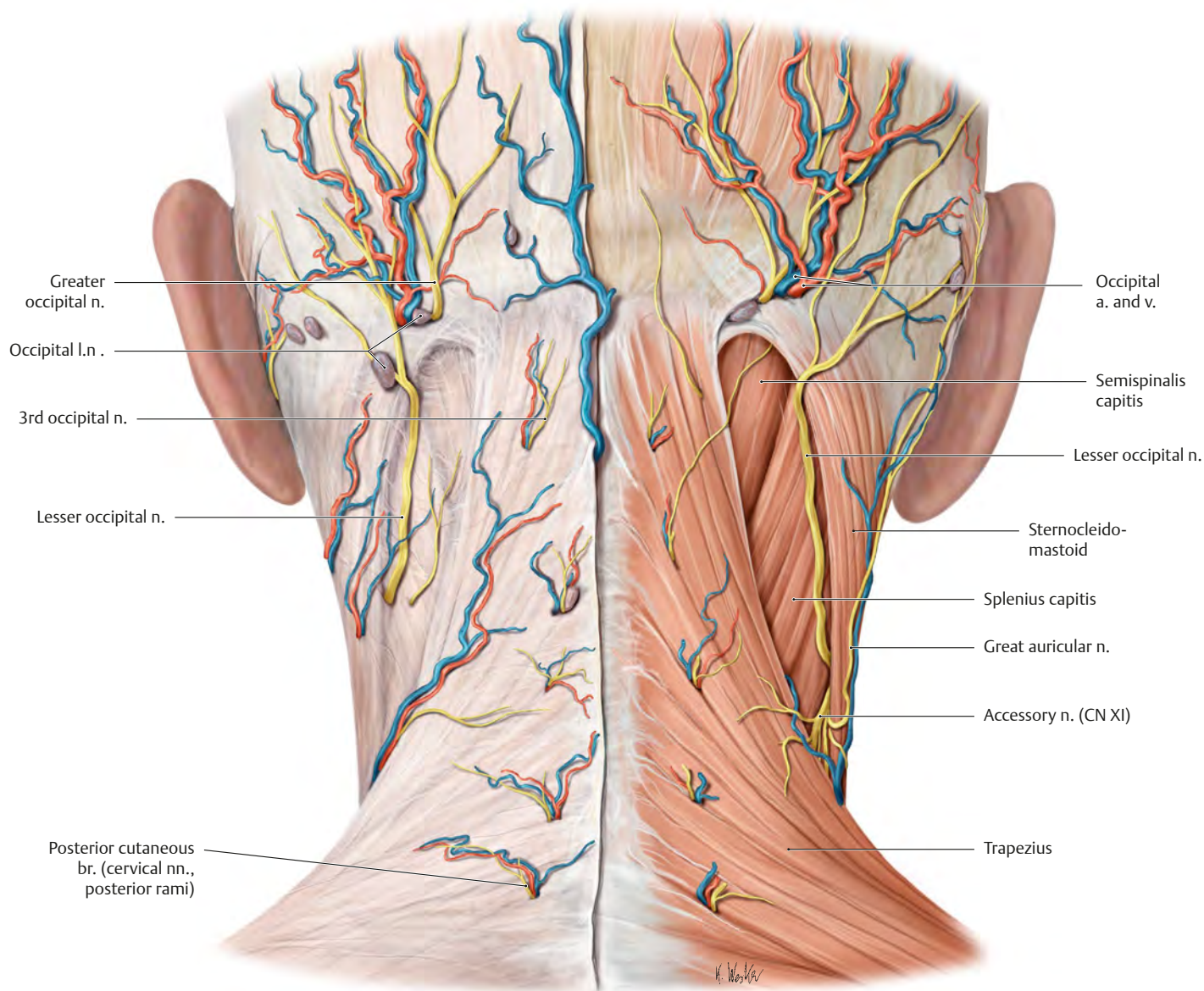
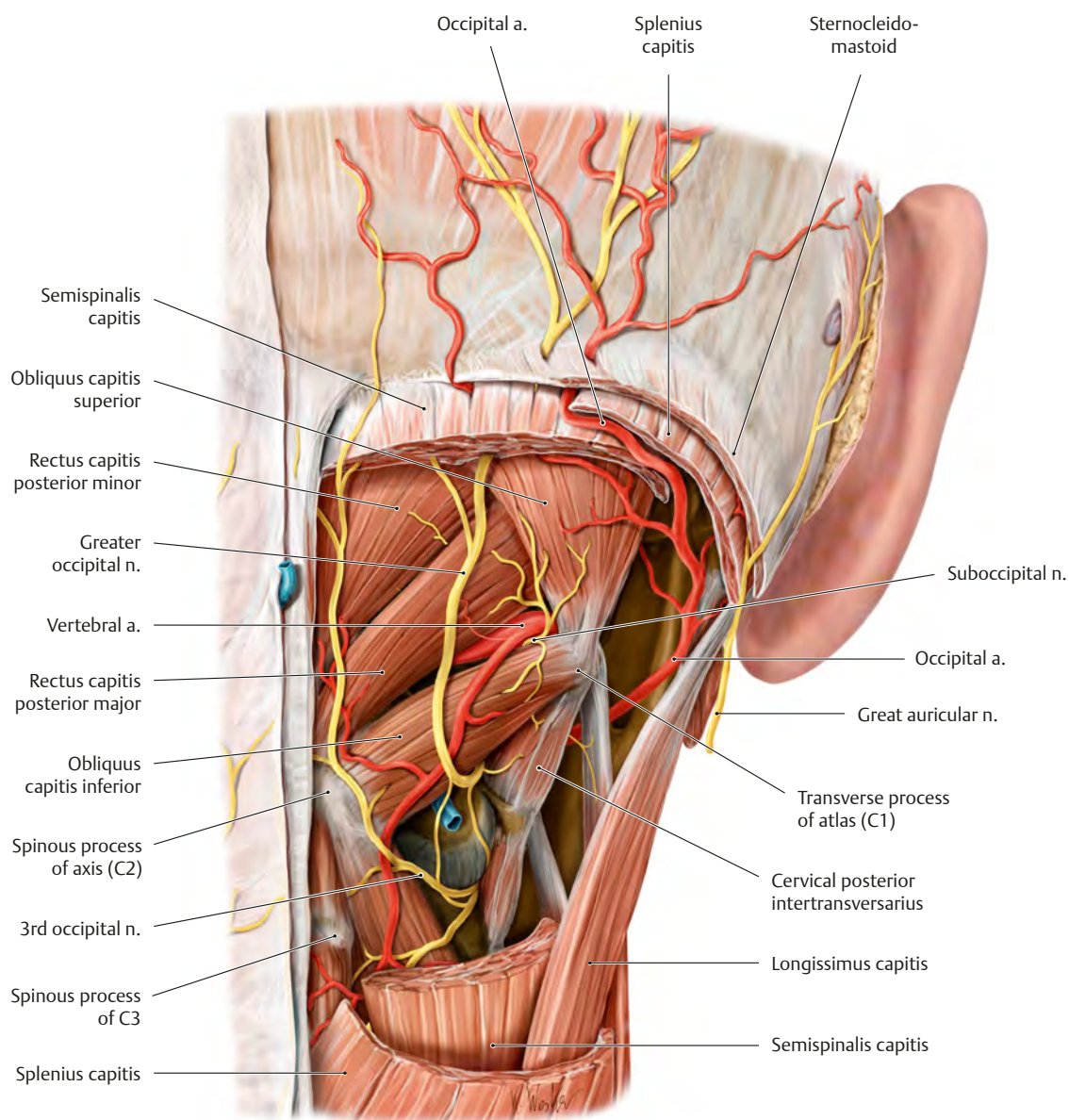


Fig. 37.38 Suboccipital triangle

Right side, posterior view, windowed. The suboccipital triangle is bounded by the suboccipital muscles (rectus capitis posterior major and obliquus capitis superior and inferior) and contains the vertebral artery. The left and right vertebral arteries pass through the atlanto-occipital membrane and combine to form the basilar artery.



38 Bones of the Head

Anterior & Lateral Skull

Fig. 38.1 Lateral skull
Left lateral view.

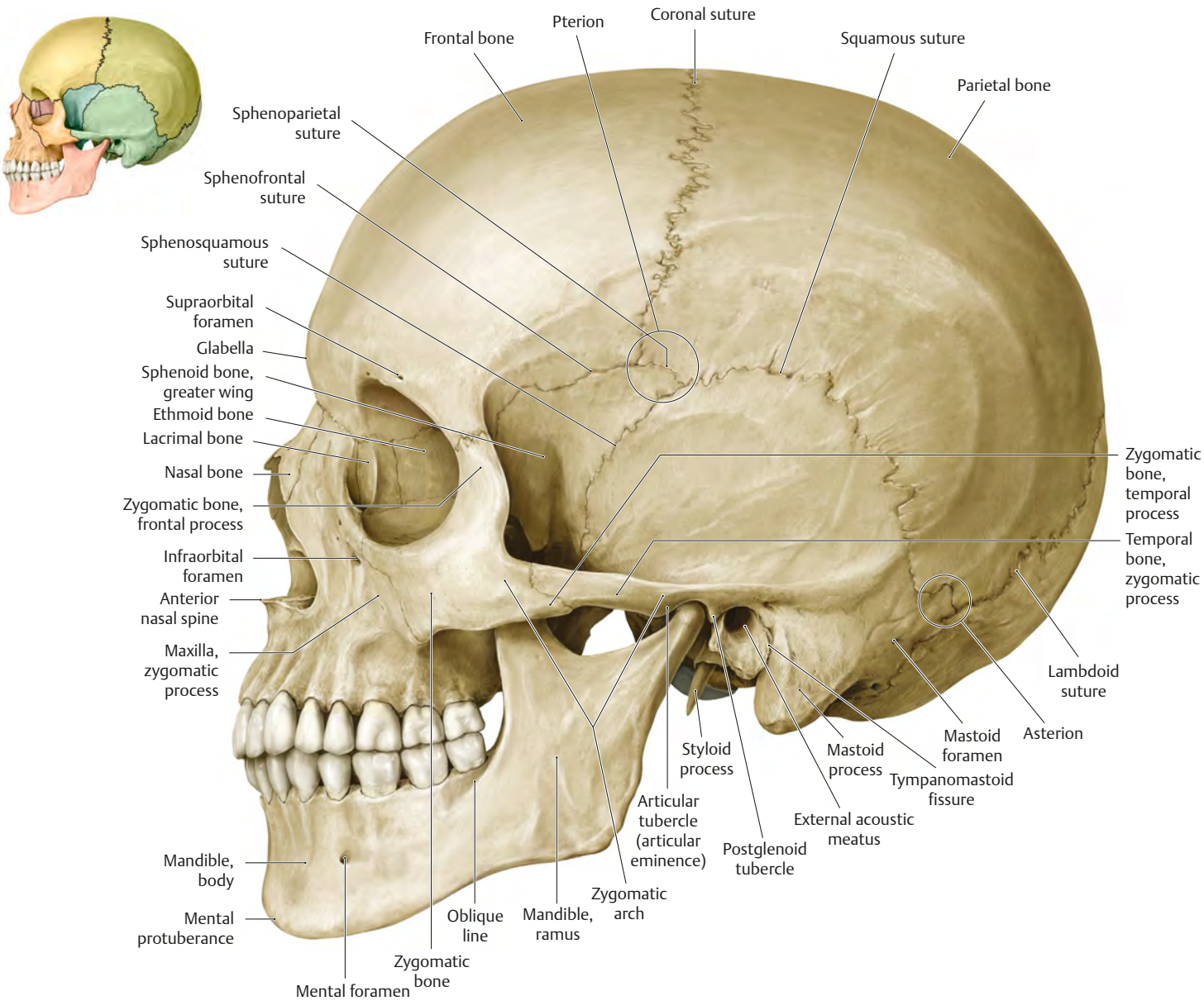


Table 38.1

Bones of the skull

The skull is subdivided into the neurocranium (gray) and viscerocranium (orange). The neurocranium protects the brain, while the viscerocranium houses and protects the facial regions.

Neurocranium

- Ethmoid bone (cribriform plate)*
- Frontal bone
- Occipital bone
- Parietal bone
- Sphenoid bone
- Temporal bone (petrous and squamous parts)

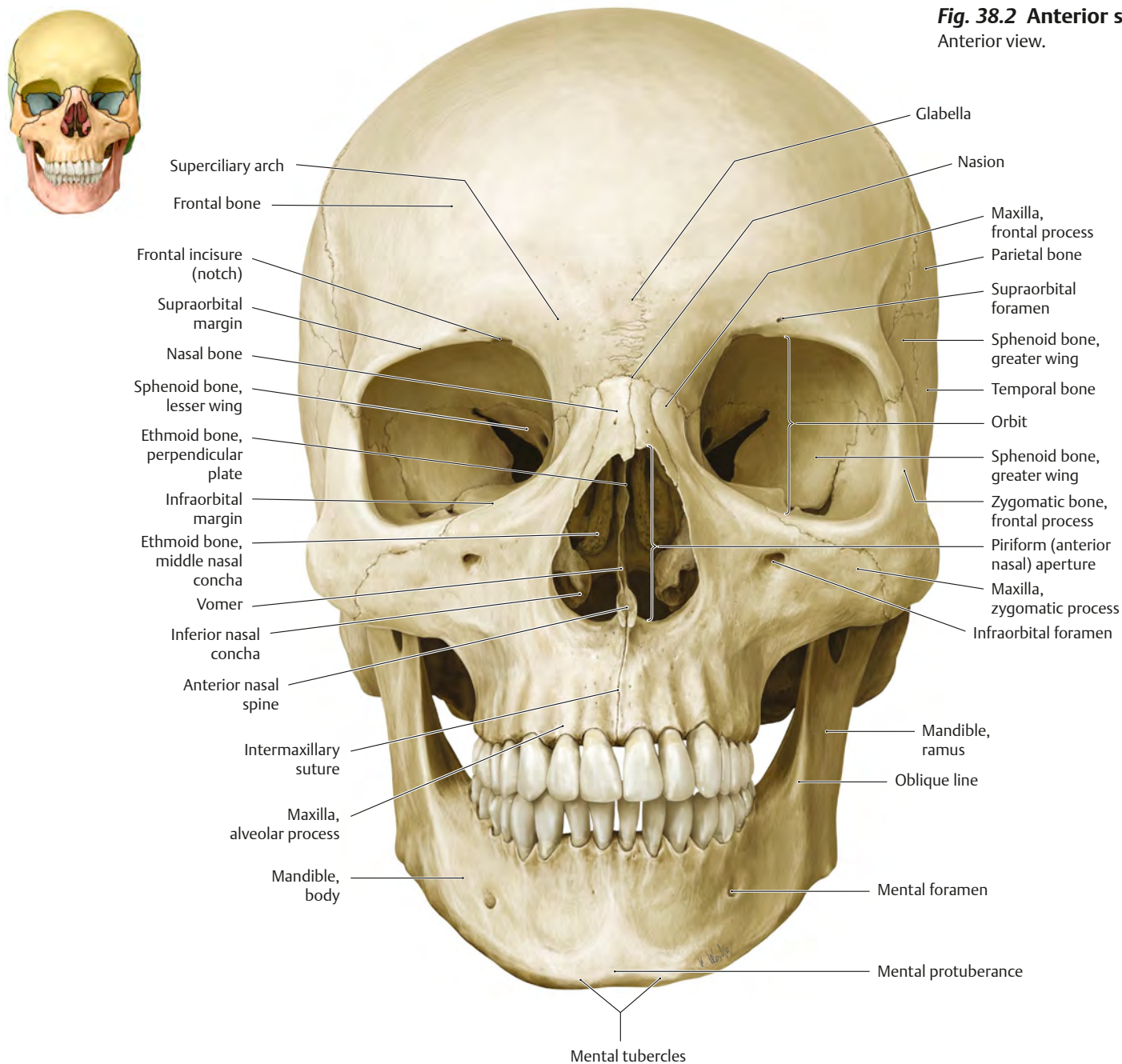
Viscerocranium

- Ethmoid bone
- Hyoid bone
- Inferior nasal concha
- Lacrimal bone
- Sphenoid bone (pterygoid process)
- Temporal bone
- Vomer
- Mandible
- Maxilla
- Nasal bone
- Palatine bone

*Most of the ethmoid bone is in the viscerocranium; most of the sphenoid bone is in the neurocranium. The temporal bone is divided between the two.



Fig. 38.2 Anterior skull
Anterior view.



Clinical box 38.1

Fractures of the face

The framelike construction of the facial skeleton leads to characteristic patterns for fracture lines (classified as Le Fort I, II, and III fractures).



A Le Fort I.



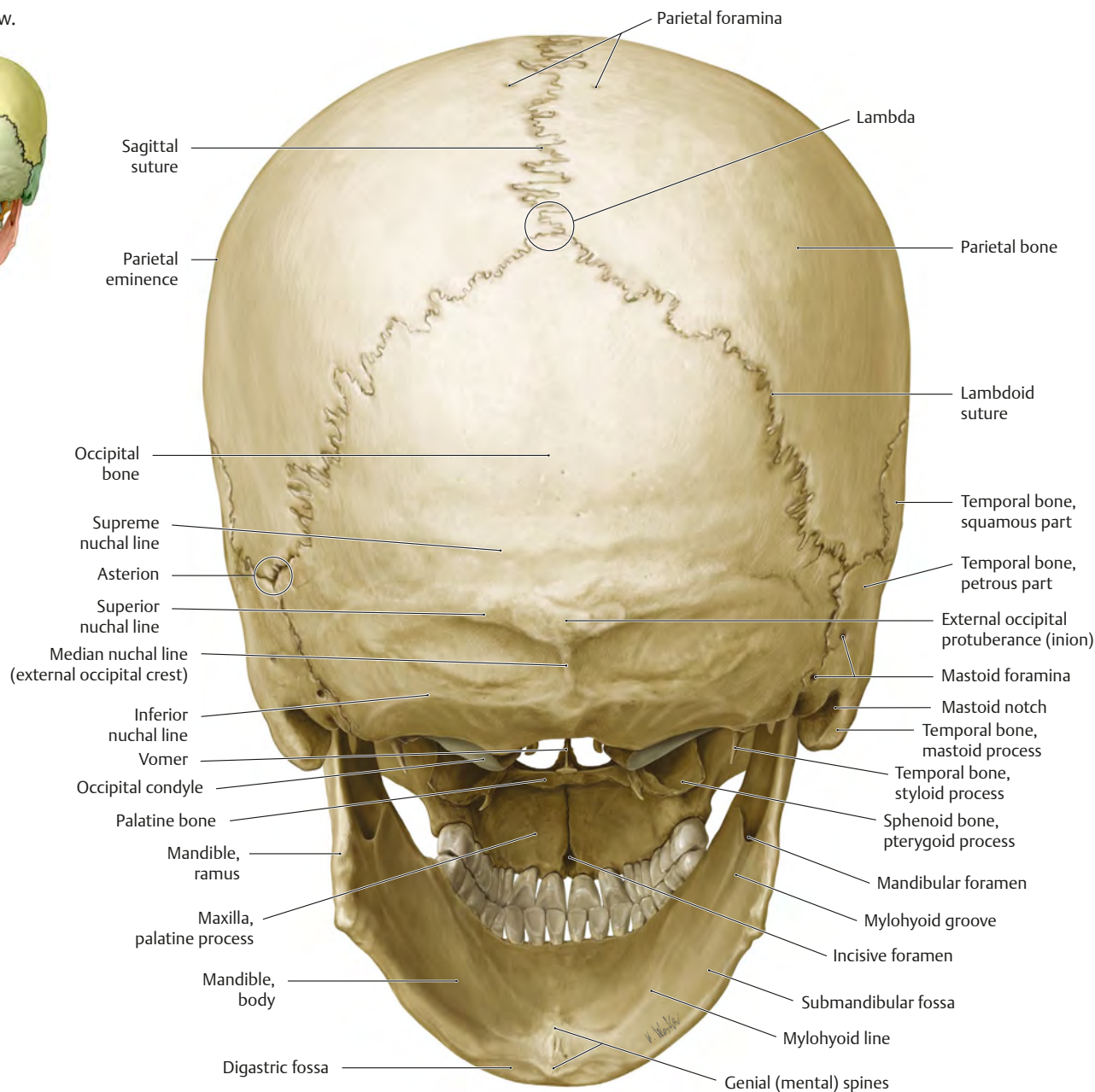
B Le Fort II.



C Le Fort III.

Posterior Skull & Calvaria

Fig. 38.3 Posterior skull
Posterior view.



Clinical box 38.2

Cranial Fontanelles

In the neonate, there are areas between still-growing cranial bones not occupied by bone: the fontanelles. While these regions close at different times, they have clinical implications. The *posterior fontanelle* provides a reference point for describing the position of the fetal head during childbirth, and the *anterior fontanelle* provides a potential access site for drawing cerebrospinal fluid in infants (e.g., in suspected meningitis).

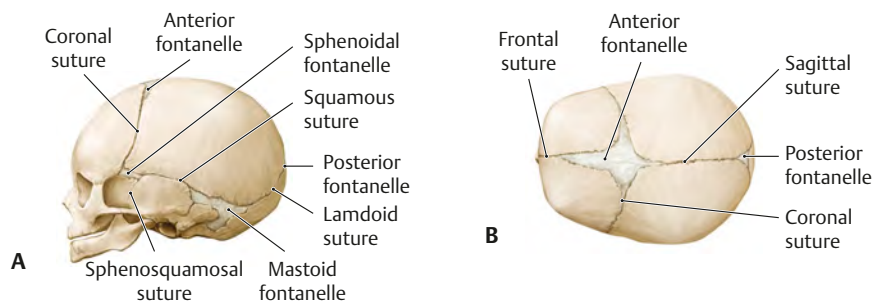
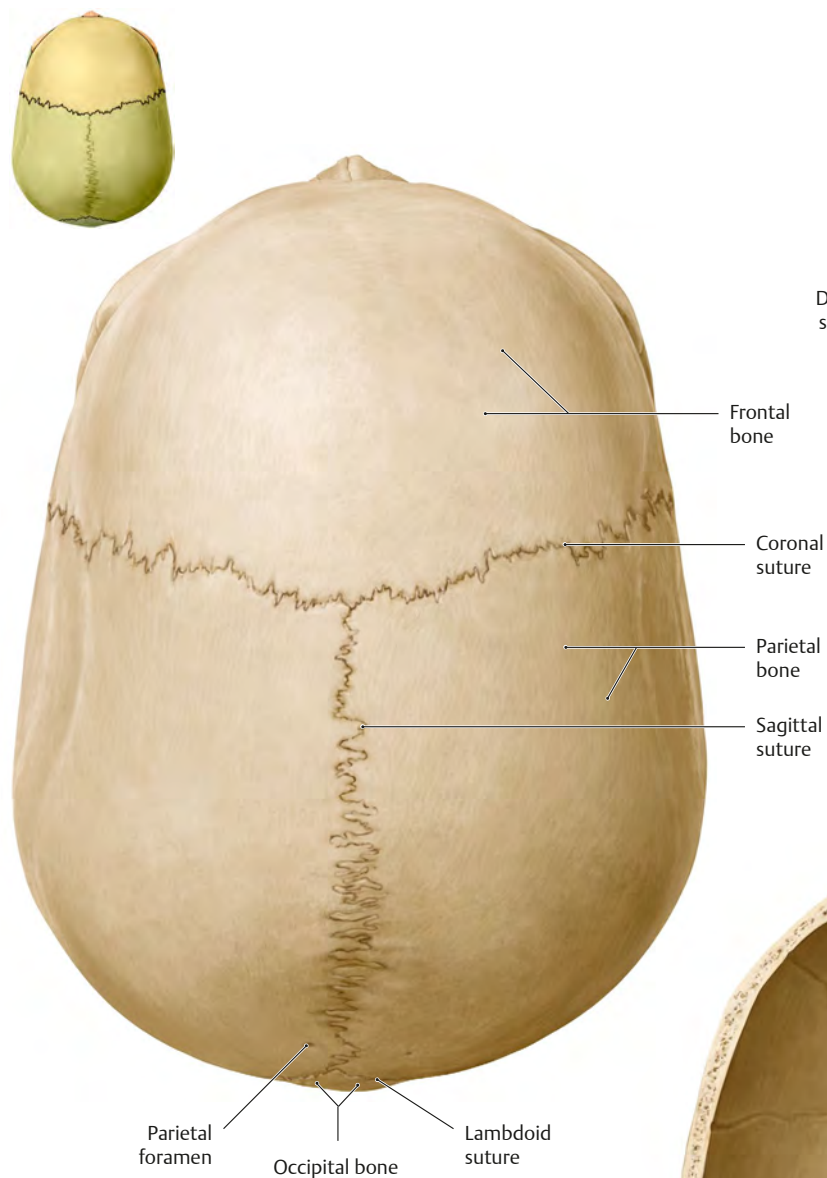
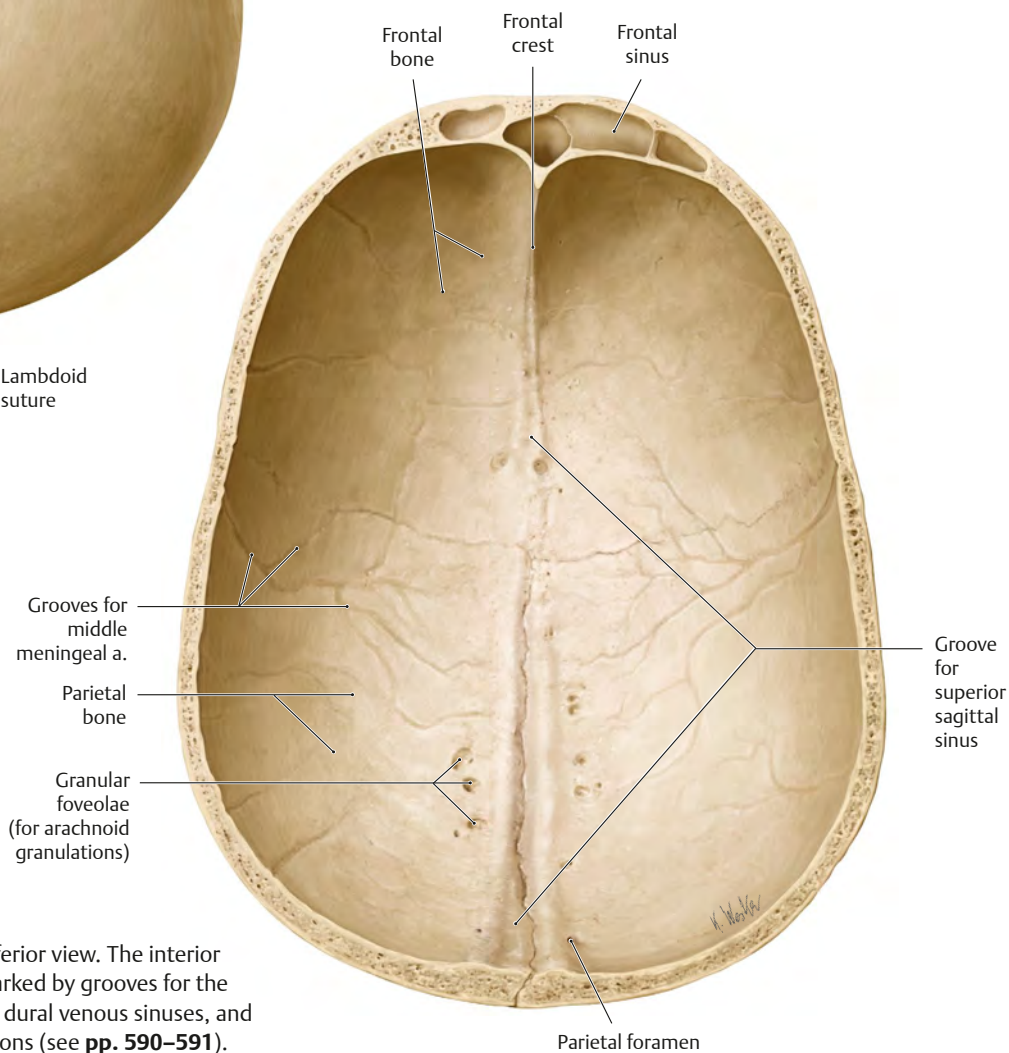
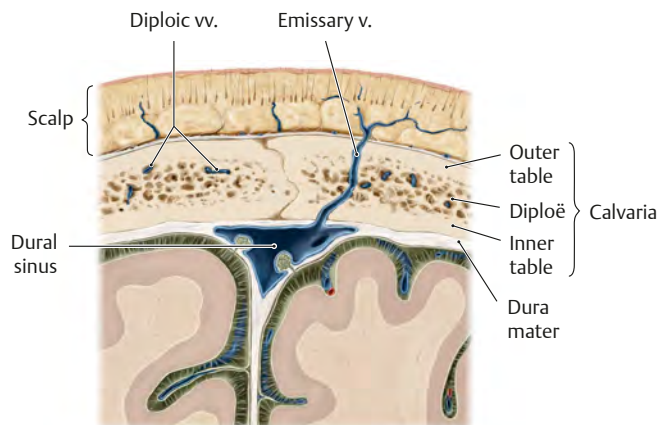


Fig. 38.4 Calvaria**A** External calvaria, superior view.**Fig. 38.5 Structure of the calvaria**
Cross section.**B** Internal calvaria, inferior view. The interior of the calvaria is marked by grooves for the meningeal arteries, dural venous sinuses, and arachnoid granulations (see pp. 590–591).

Base of the Skull

Fig. 38.6 Base of the skull: Exterior

Inferior view. *Revealed:* Foramina and canals for blood vessels (see p. 582) and cranial nerves. *Note:* This view allows visual access into the posterior region of the nasal cavity.

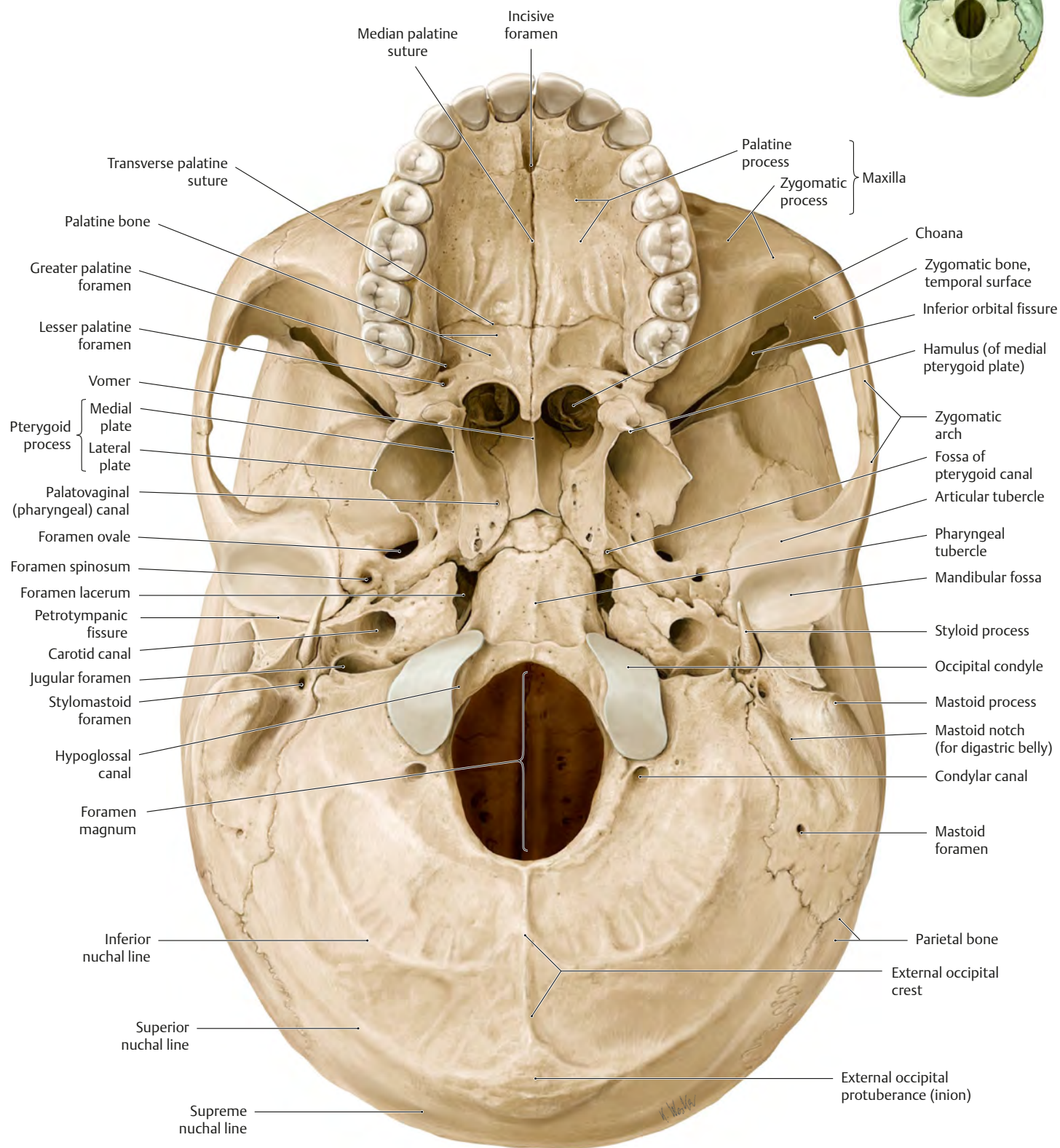
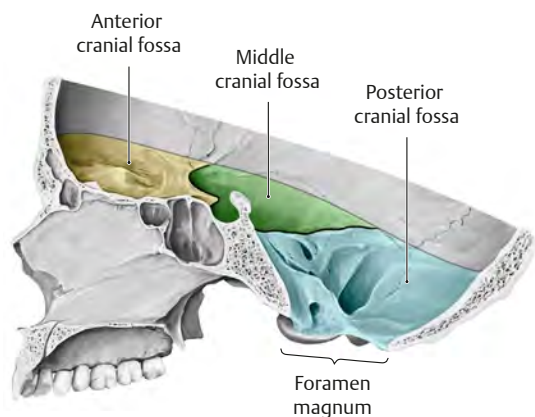
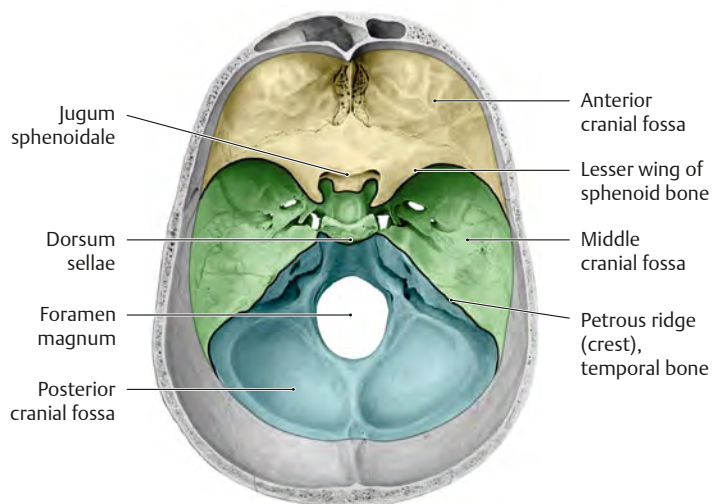
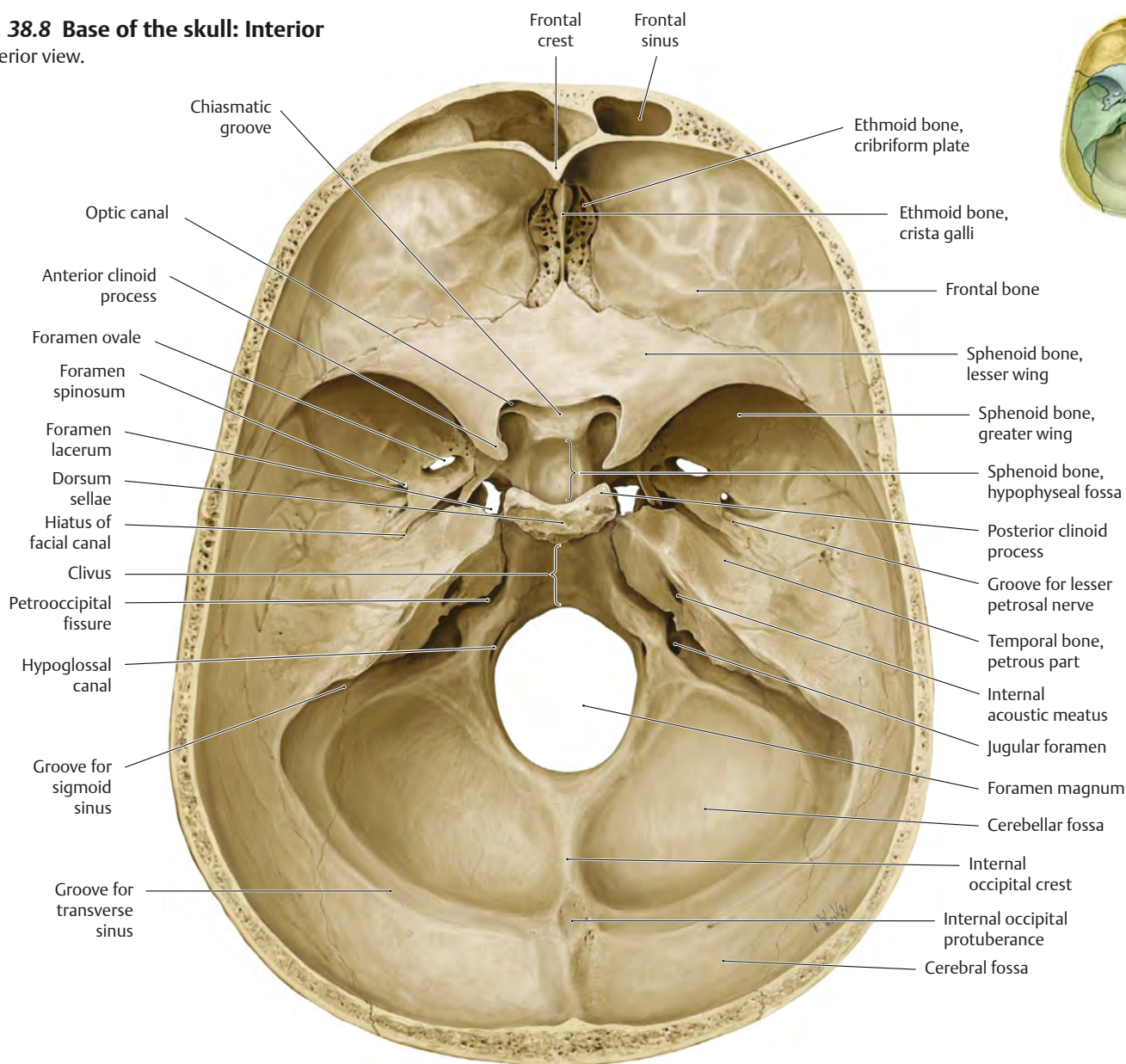


Fig. 38.7 Cranial fossae

The interior of the skull base consists of three successive fossae that become progressively deeper in the frontal-to-occipital direction.

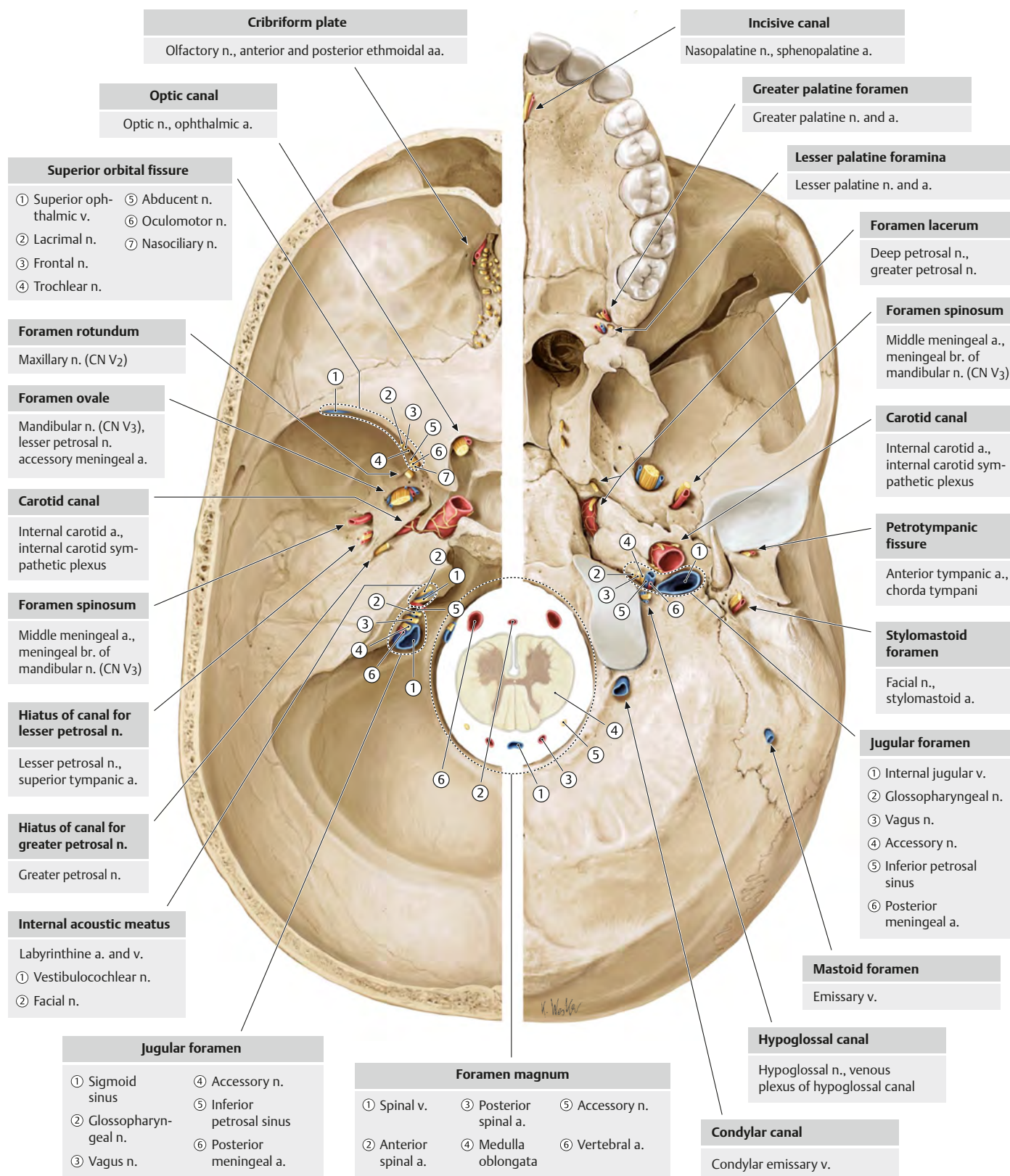
**A** Midsagittal section, left lateral view.**B** Superior view of opened skull.**Fig. 38.8 Base of the skull: Interior**

Superior view.



Neurovascular Pathways Exiting or Entering the Cranial Cavity

Fig. 38.9 Summary of the neurovascular structures exiting or entering the cranial cavity

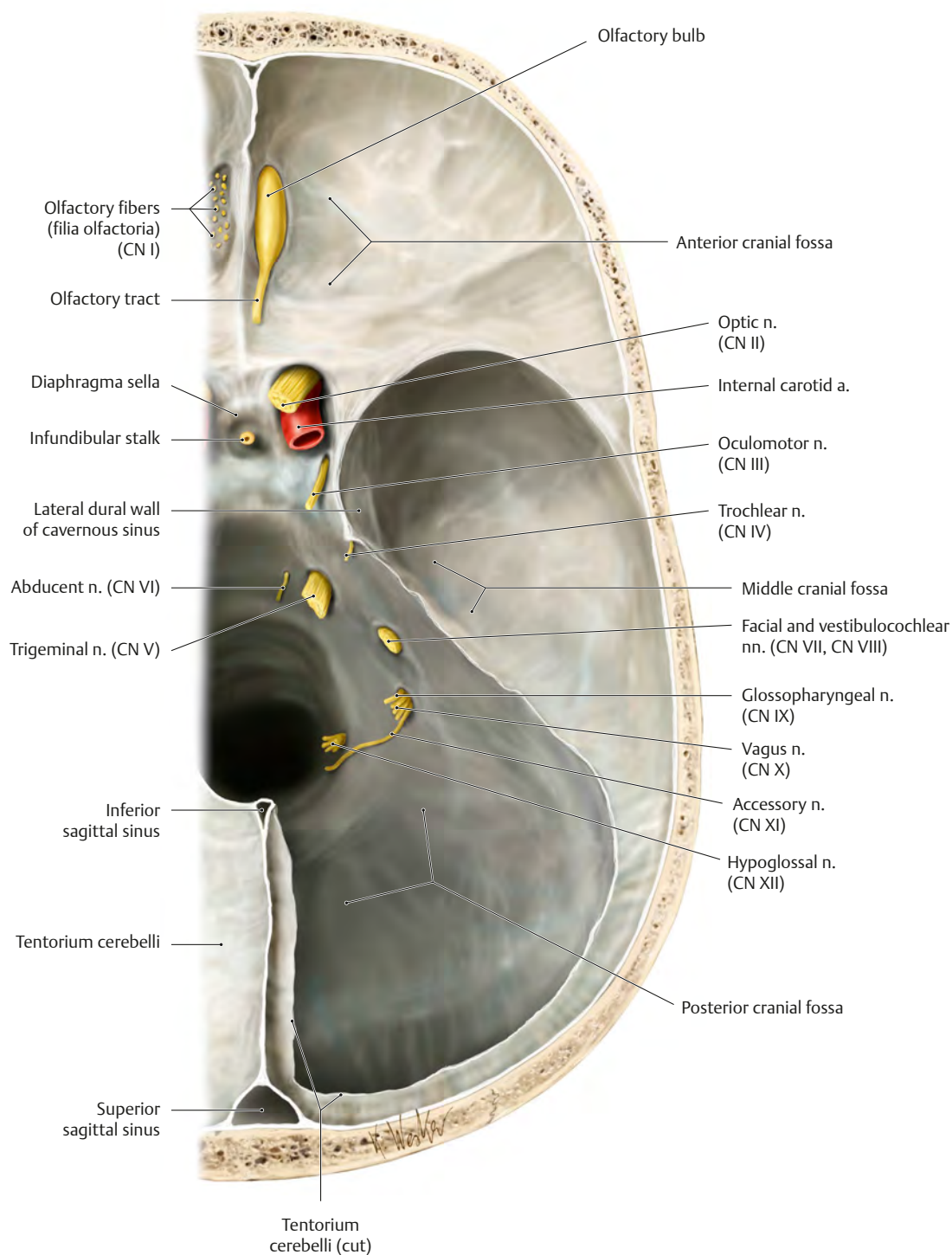


A Cranial cavity (interior of skull base), left side, superior view.

B Exterior of skull base, left side, inferior view

Fig. 38.10 Cranial nerves exiting the cranial cavity

Cranial cavity (interior of skull base), right side, superior view. *Removed:* Brain and tentorium cerebelli. The ends of the cranial nerves have been cut to reveal the fissures, fossae, or dural cave where they pass through the cranial fossa.



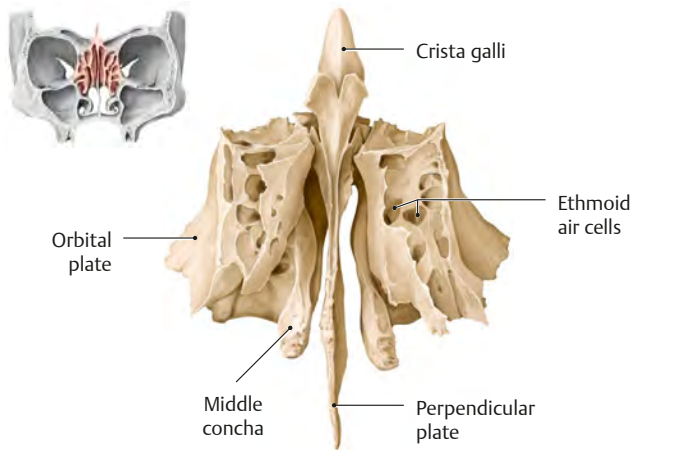
Ethmoid & Sphenoid Bones

The structurally complex ethmoid and sphenoid bones are shown here in isolation. The other bones of the skull are shown in their respective

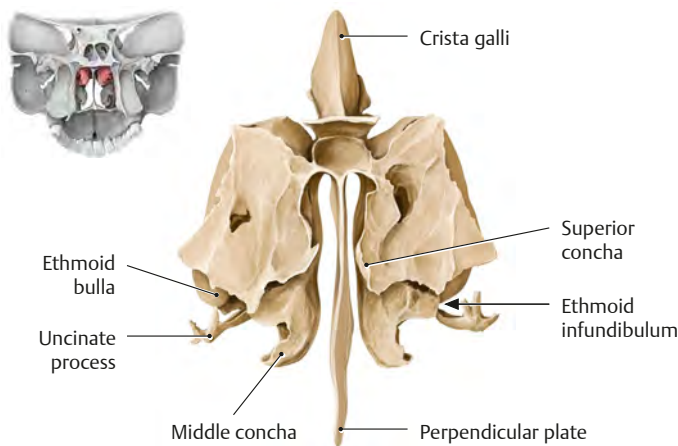
regions: orbit (see pp. 602–603), nasal cavity (see pp. 616–617), oral cavity (see pp. 636–637), and ear (see pp. 624–625).

Fig. 38.11 Ethmoid bone

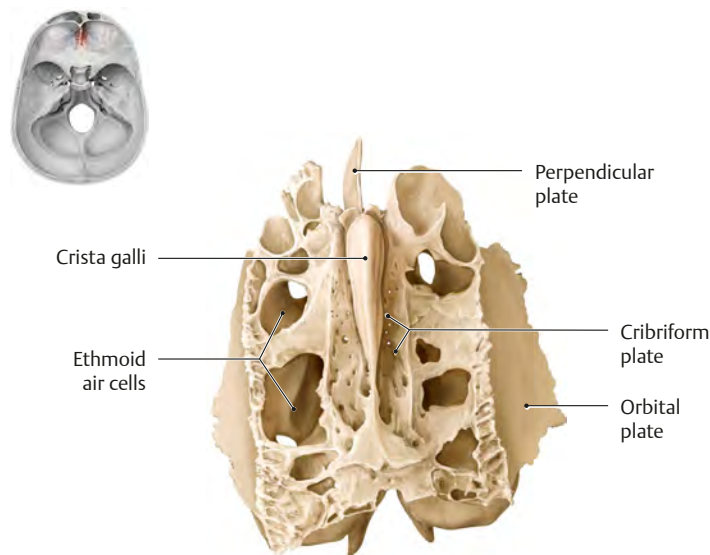
The ethmoid bone is the central bone of the nose and paranasal air sinuses (see pp. 616–619).



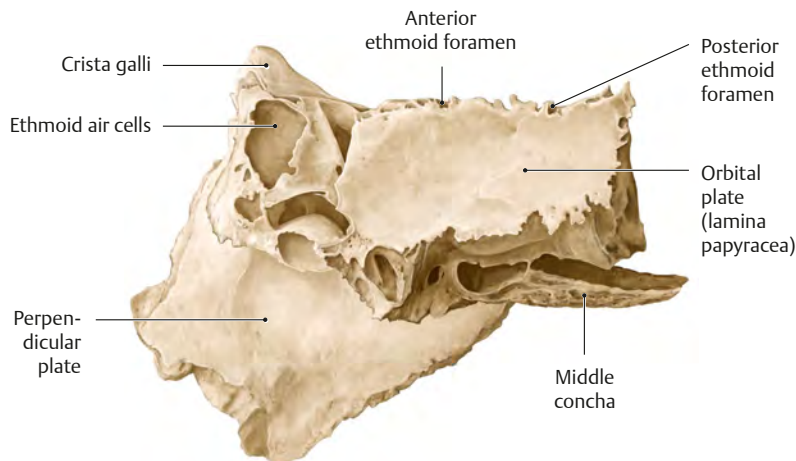
A Anterior view.



C Posterior view.



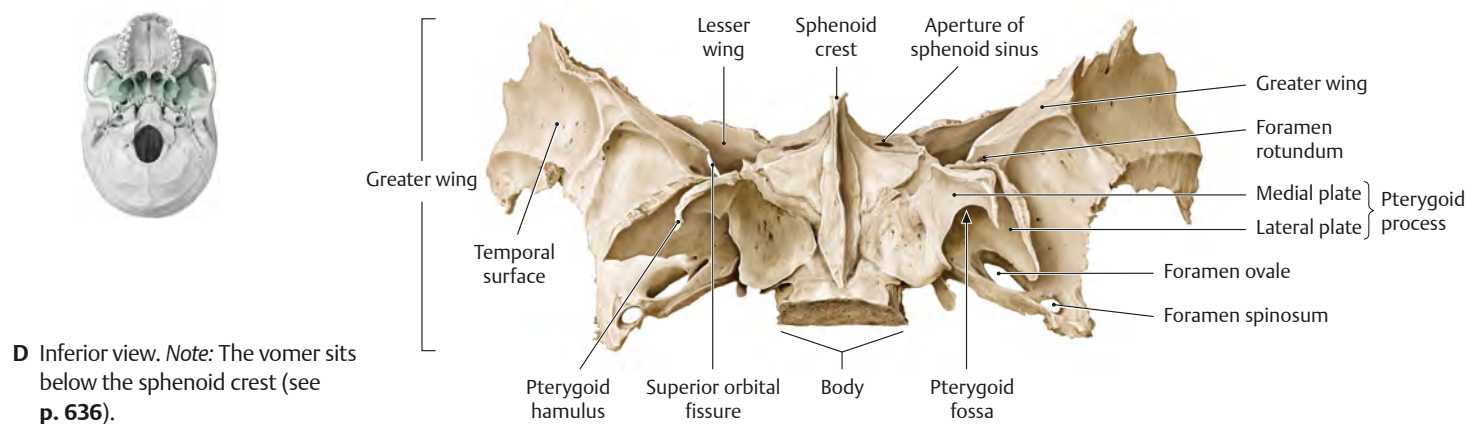
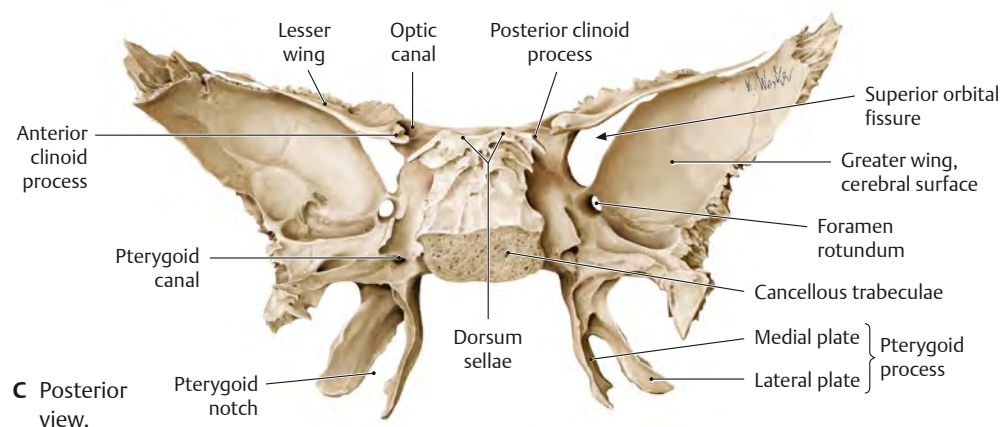
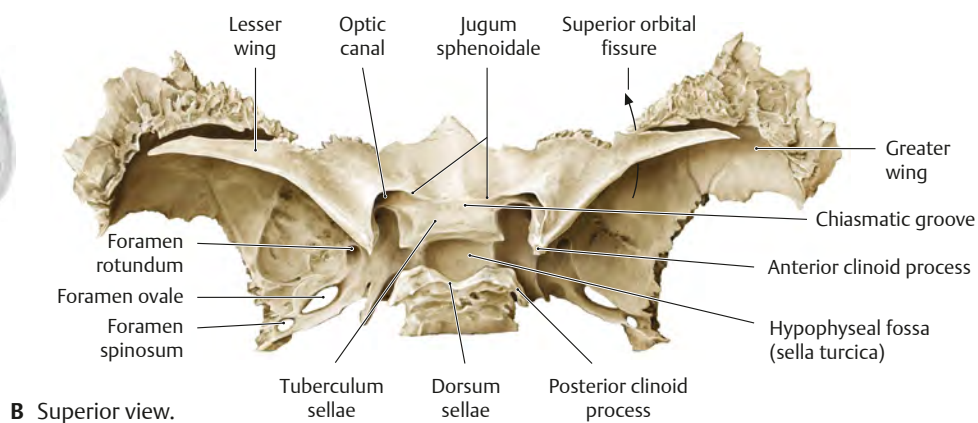
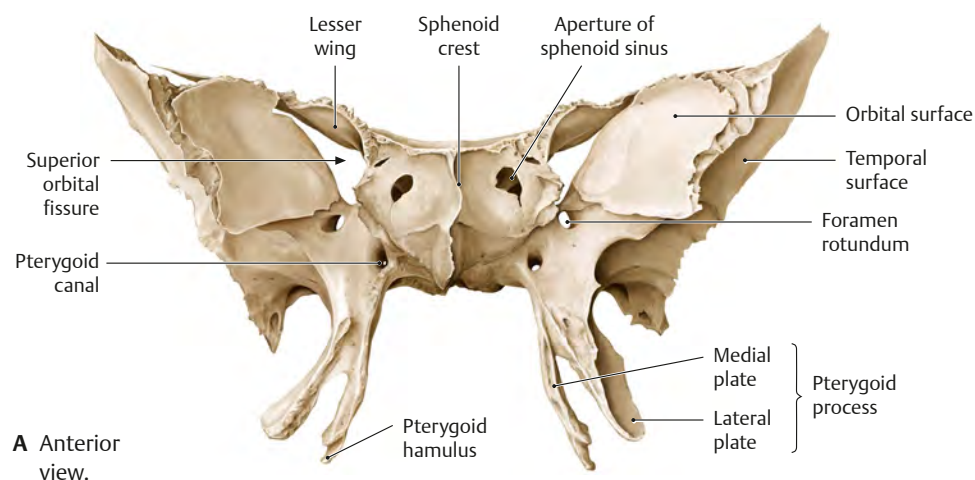
B Superior view.



D Left lateral view.

Fig. 38.12 Sphenoid bone

The sphenoid bone is the most structurally complex bone in the human body.



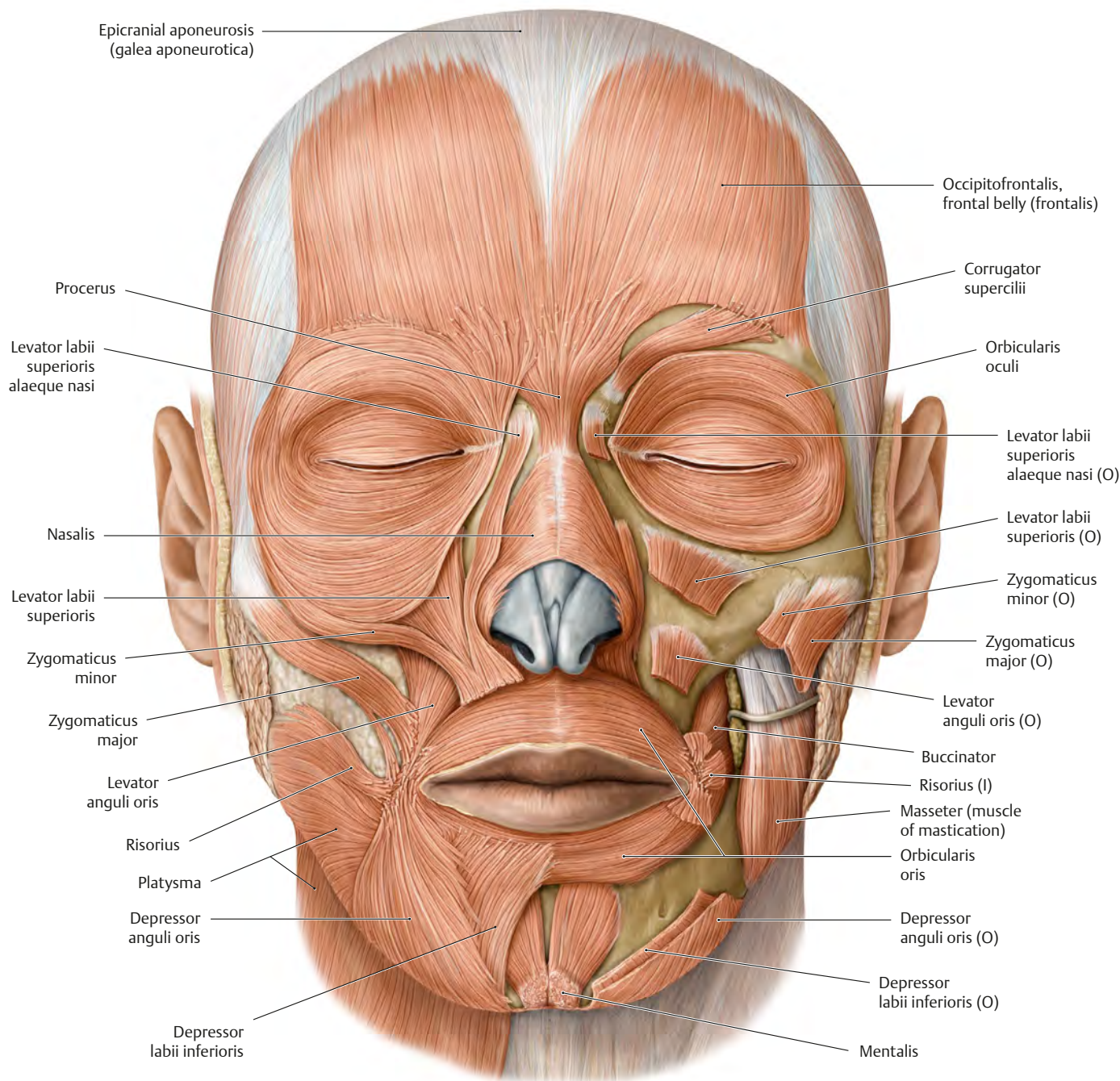
39 Muscles of the Skull & Face

Muscles of Facial Expression & of Mastication

The muscles of the skull and face are divided into two groups. The muscles of facial expression make up the superficial muscle layer in

the face. The muscles of mastication are responsible for the movement of the mandible during mastication (chewing).

Fig. 39.1 Muscles of facial expression



A Anterior view. Muscle origins (O) and insertions (I) indicated on left side of face.

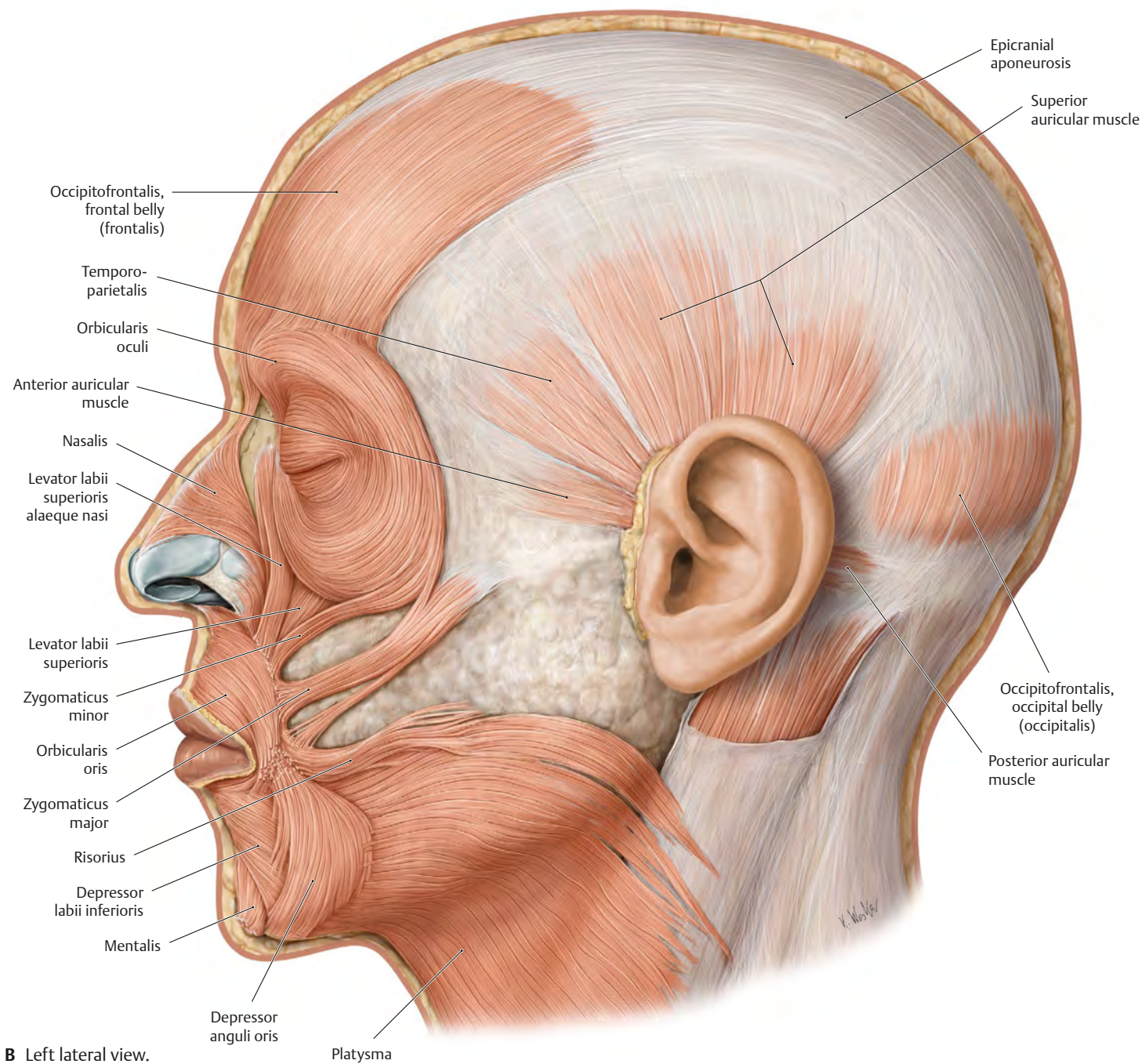
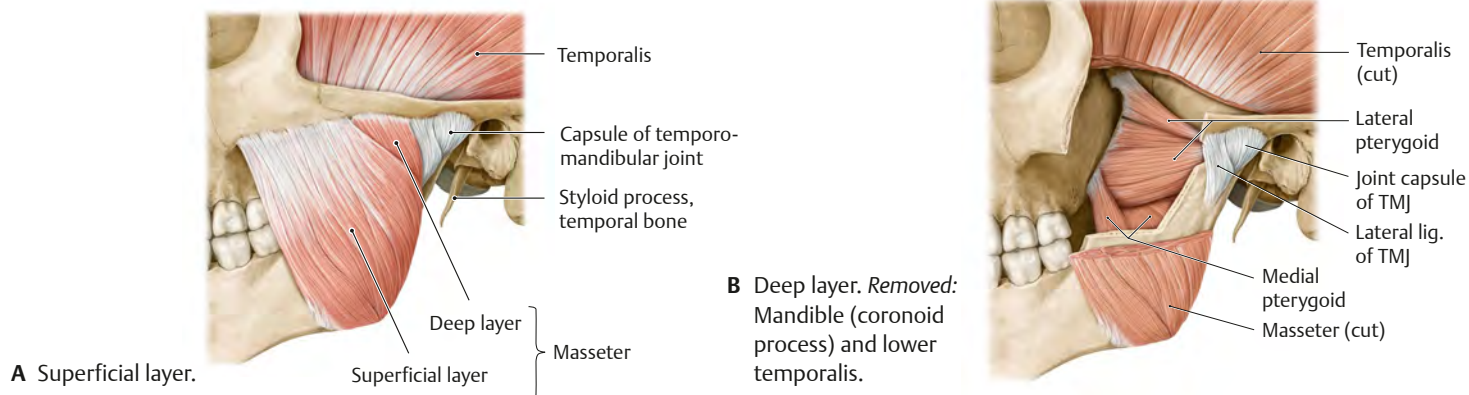


Fig. 39.2 Muscles of mastication

Left lateral view.



Muscle Origins & Insertions on the Skull

Fig. 39.3 Lateral skull: Origins and insertions

Left lateral view. Muscle origins are shown in red, insertions in blue. *Note:* There are generally no bony insertions for the muscles of facial expression. These muscles insert into skin and other muscles of facial expression.

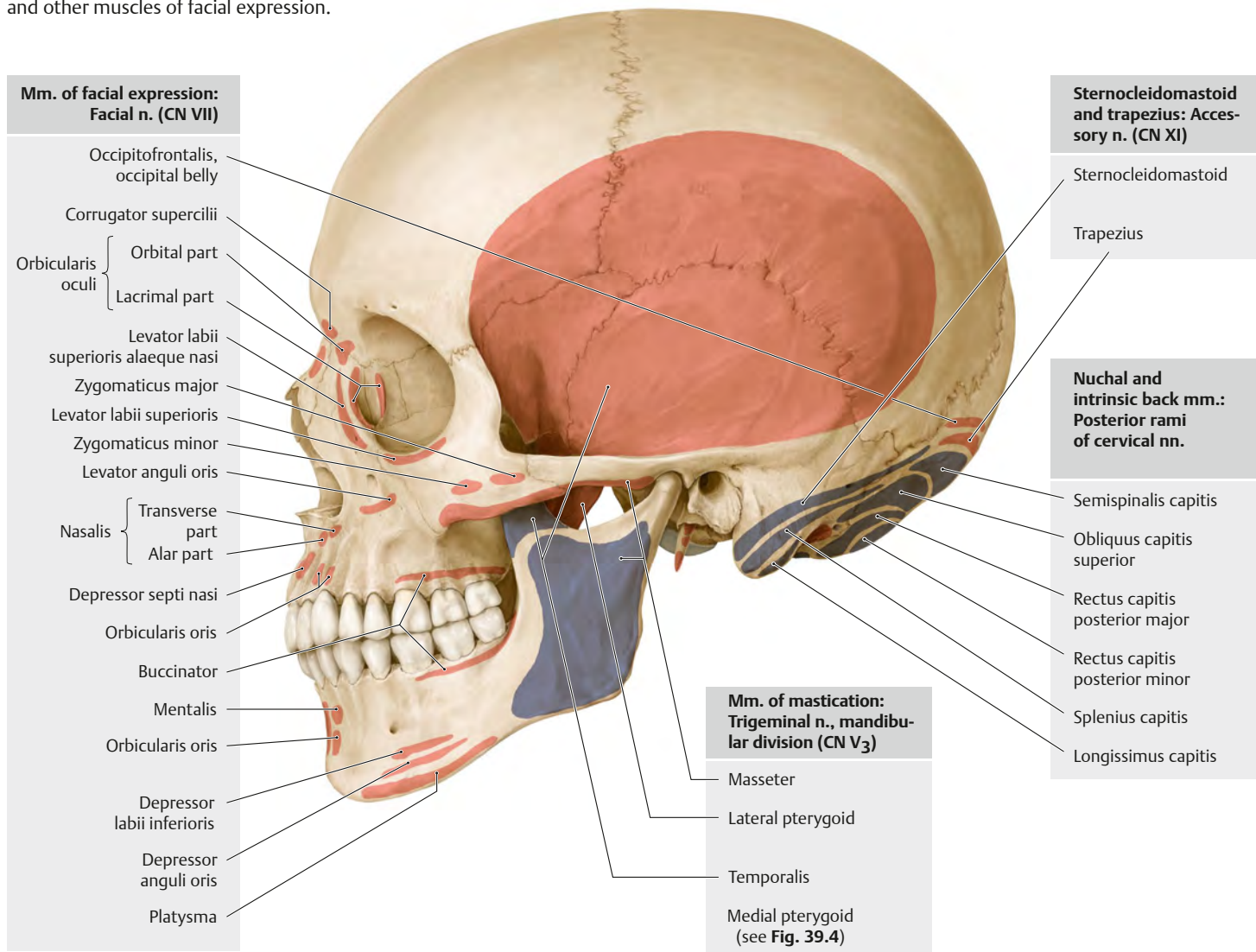


Fig. 39.4 Mandible: Origins and insertions

Medial view of right hemimandible (inner surface). Muscle origins are shown in red, insertions in blue.

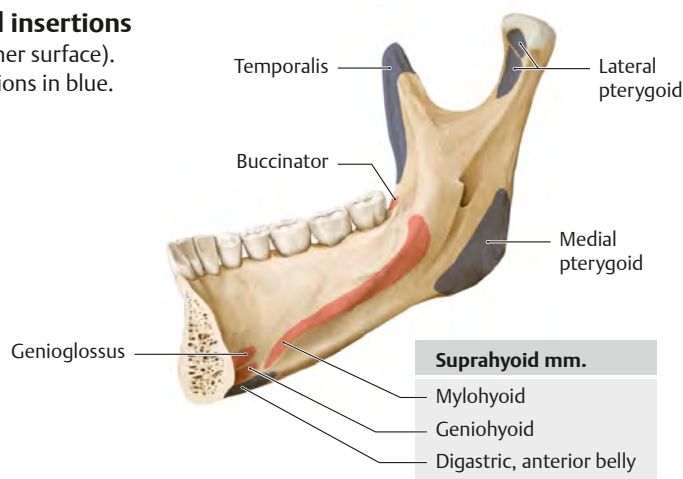
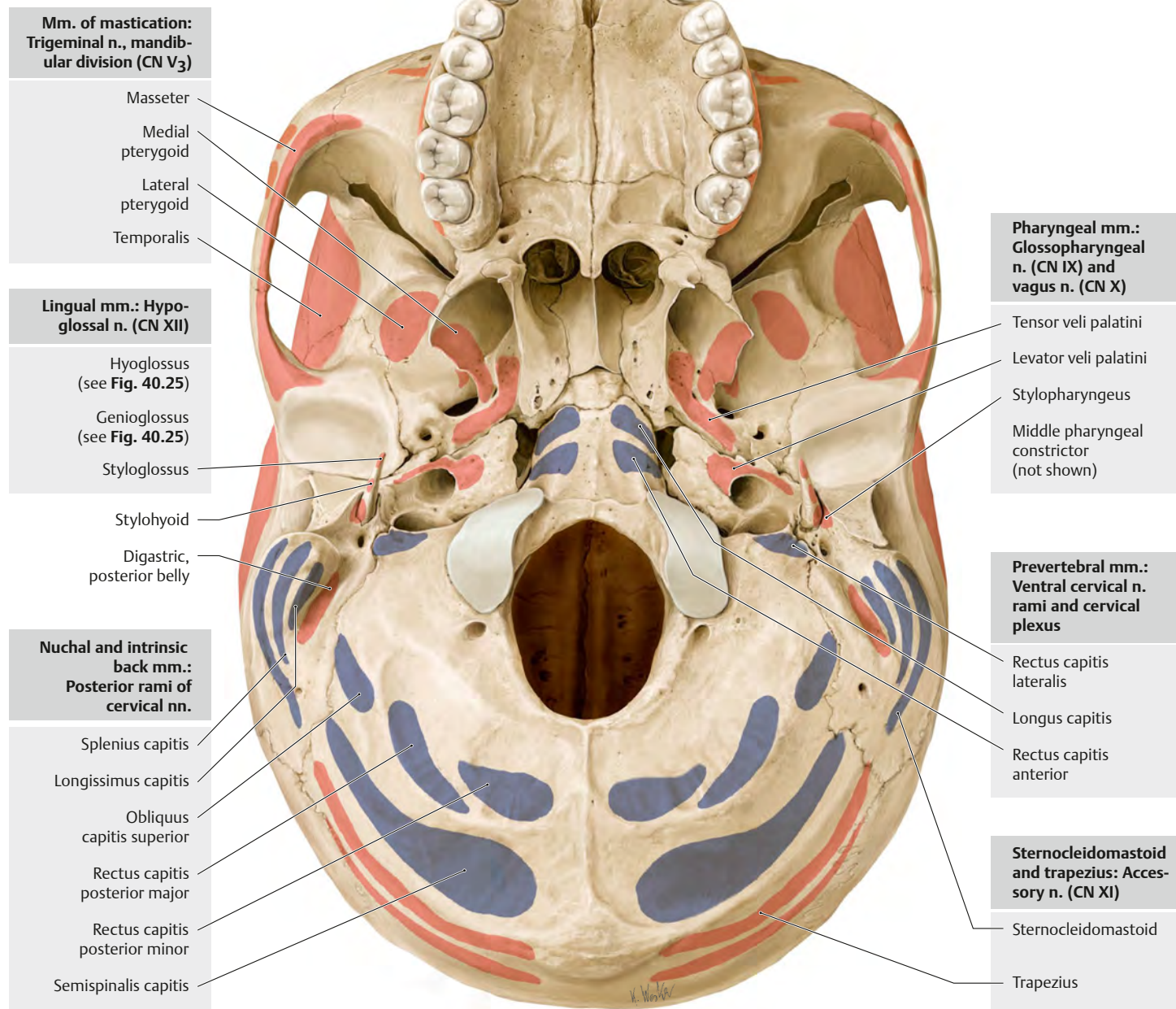


Fig. 39.5 Skull base: Origins and insertions

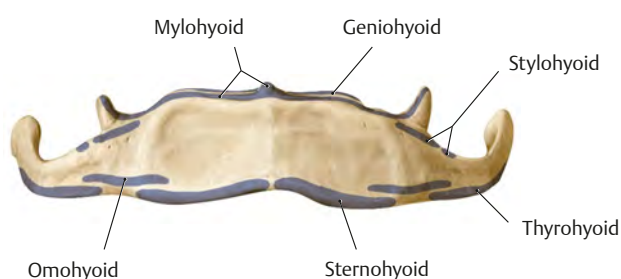
Inferior view of external skull.

Muscle origins are shown in red, insertions in blue.

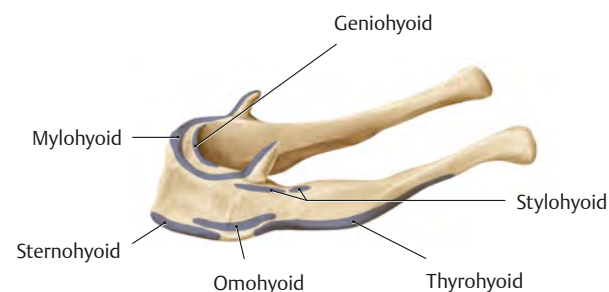
**Fig. 39.6 Hyoid bone: Origins and insertions**

The larynx is suspended from the hyoid bone, primarily by the thyrohyoid membrane. The hyoid bone is the site for attachment for

the suprahyoid and infrahyoid muscles. Muscle insertions are shown in blue.



A Anterior view.



B Oblique left lateral view.

Muscle Facts (I)

The muscles of facial expression originate on bone and/or fascia and insert into the subcutaneous tissue of the face. This allows them to produce their effects by pulling on the skin.

Fig. 39.7 Occipitofrontalis
Anterior view.

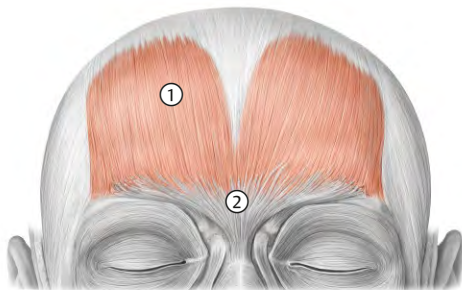


Fig. 39.9 Muscles of the ear
Left lateral view.

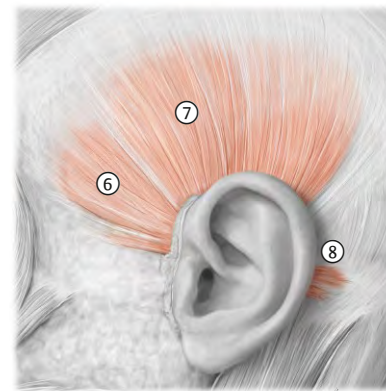
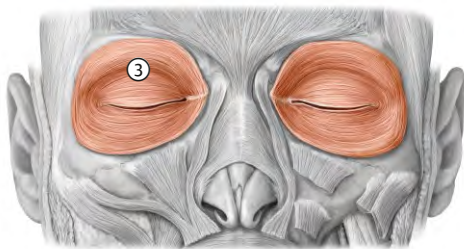
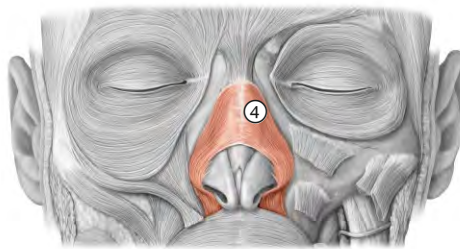


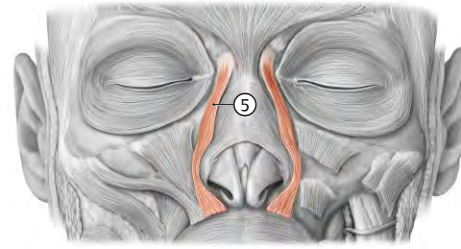
Fig. 39.8 Muscles of the palpebral fissure and nose
Anterior view.



A Orbicularis oculi.



B Nasalis.



C Levator labii superioris alaeque nasi.

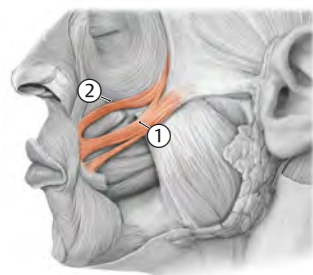
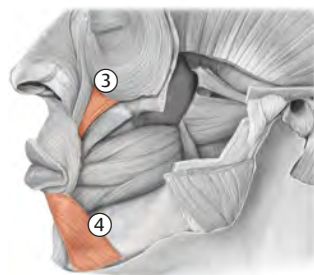
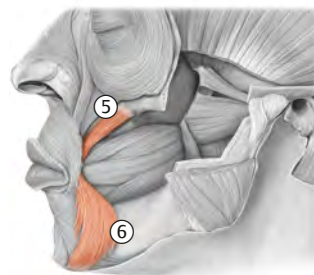
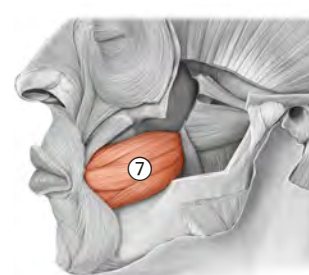
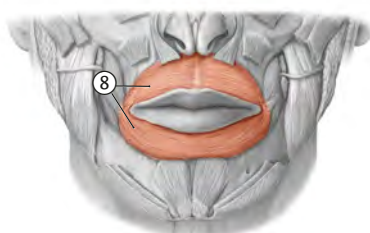
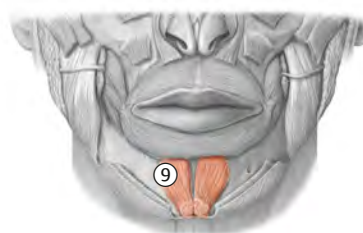
Table 39.1

Muscles of facial expression: Forehead, nose, and ear

Muscle	Origin	Insertion*	Main action(s)**
Calvaria			
① Occipitofrontalis (frontal belly)	Epicranial aponeurosis	Skin and subcutaneous tissue of eyebrows and forehead	Elevates eyebrows, wrinkles skin of forehead
Palpebral fissure and nose			
② Procerus	Nasal bone, lateral nasal cartilage (upper part)	Skin of lower forehead between eyebrows	Pulls medial angle of eyebrows inferiorly, producing transverse wrinkles over bridge of nose
③ Orbicularis oculi	Medial orbital margin, medial palpebral ligament, lacrimal bone	Skin around margin of orbit, superior and inferior tarsal plates	Acts as orbital sphincter (closes eyelids) • Palpebral portion gently closes • Orbital portion tightly closes (as in winking)
④ Nasalis	Maxilla (superior region of canine ridge)	Nasal cartilages	Flares nostrils by drawing ala (side) of nose toward nasal septum
⑤ Levator labii superioris alaeque nasi	Maxilla (frontal process)	Alar cartilage of nose and upper lip	Elevates upper lip, opens nostril
Ear			
⑥ Anterior auricular muscle	Temporal fascia (anterior portion)	Helix of the ear	Pulls ear superiorly and anteriorly
⑦ Superior auricular muscle	Epicranial aponeurosis on side of head	Upper portion of auricle	Elevates ear
⑧ Posterior auricular muscle	Mastoid process	Convexity of concha of ear	Pulls ear superiorly and posteriorly

*There are no bony insertions for the muscles of facial expression.

**All muscles of facial expression are innervated by the facial nerve (CN VII) via temporal, zygomatic, buccal, mandibular, or cervical branches arising from the parotid plexus (see pp. 568–569).

Fig. 39.10 Muscles of the mouth**A** Zygomaticus major and minor, left lateral view.**B** Levator labii superioris and depressor labii inferioris, left lateral view.**C** Levator and depressor anguli oris, left lateral view.**D** Buccinator, left lateral view.**E** Orbicularis oris, anterior view.**F** Mentalis, anterior view.**Table 39.2 Muscles of facial expression: Mouth and neck**

Muscle	Origin	Insertion*	Main action(s)**
Mouth			
① Zygomaticus major	Zygomatic bone (lateral surface, posterior part)	Skin at corner of the mouth	Pulls corner of mouth superiorly and laterally
② Zygomaticus minor		Upper lip just medial to corner of the mouth	Pulls upper lip superiorly
Levator labii superioris alaeque nasi (see Fig. 39.8C)	Maxilla (frontal process)	Alar cartilage of nose and upper lip	Elevates upper lip, opens nostril
③ Levator labii superioris	Maxilla (frontal process) and infraorbital region	Skin of upper lip, alar cartilages of nose	Elevates upper lip, dilates nostril, raises angle of the mouth
④ Depressor labii inferioris	Mandible (anterior portion of oblique line)	Lower lip at midline; blends with muscle from opposite side	Pulls lower lip inferiorly and laterally
⑤ Levator anguli oris	Maxilla (below infraorbital foramen)	Skin at corner of the mouth	Raises angle of mouth, helps form nasolabial furrow
⑥ Depressor anguli oris	Mandible (oblique line below canine, premolar, and first molar teeth)	Skin at corner of the mouth; blends with orbicularis oris	Pulls angle of mouth inferiorly and laterally
⑦ Buccinator	Mandible, alveolar processes of maxilla and mandible, pterygo-mandibular raphe	Angle of mouth, orbicularis oris	Presses cheek against molar teeth, working with tongue to keep food between occlusal surfaces and out of oral vestibule; expels air from oral cavity/resists distension when blowing <i>Unilateral:</i> Draws mouth to one side
⑧ Orbicularis oris	Deep surface of skin Superiorly: maxilla (median plane) Inferiorly: mandible	Mucous membrane of lips	Acts as oral sphincter • Compresses and protrudes lips (e.g., when whistling, sucking, and kissing) • Resists distension (when blowing)
Risorius (see pp. 552–553)	Fascia over masseter	Skin of corner of the mouth	Retracts corner of mouth as in grimacing
⑨ Mentalis	Mandible (incisive fossa)	Skin of chin	Elevates and protrudes lower lip
Neck			
Platysma (see pp. 552–553)	Skin over lower neck and upper lateral thorax	Mandible (inferior border), skin over lower face, angle of mouth	Depresses and wrinkles skin of lower face and mouth; tenses skin of neck; aids in forced depression of the mandible

*There are no bony insertions for the muscles of facial expression.

**All muscles of facial expression are innervated by the facial nerve (CN VII) via temporal, zygomatic, buccal, mandibular, or cervical branches arising from its parotid plexus.

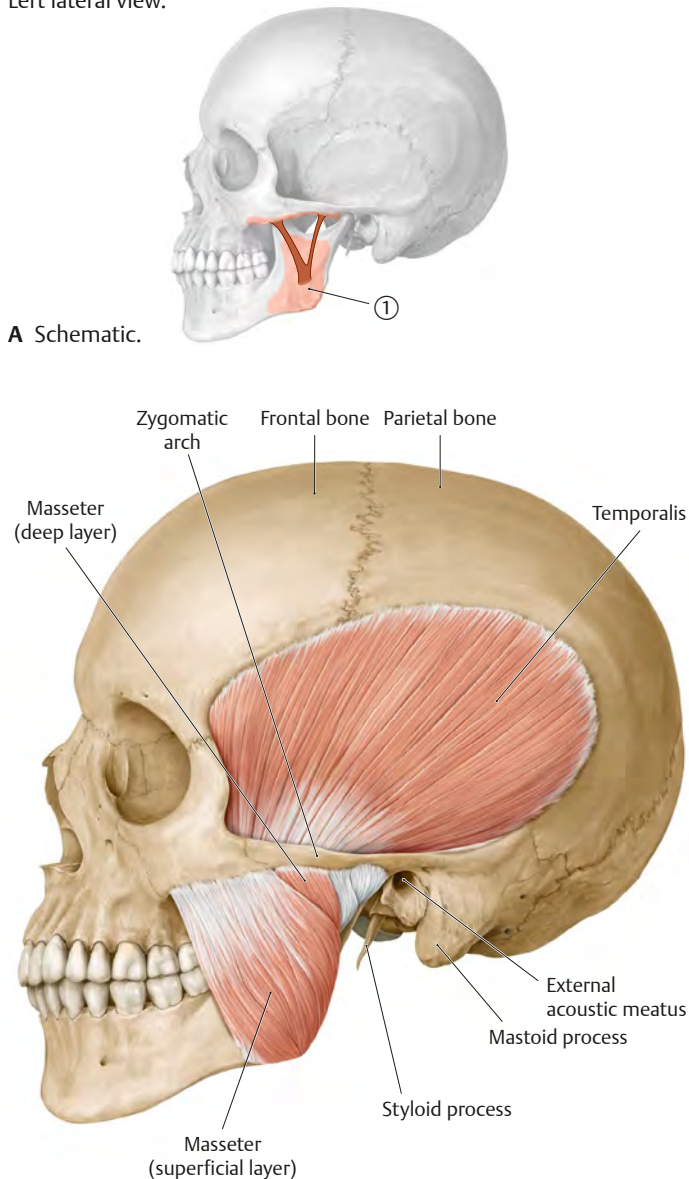
Muscle Facts (II)

The muscles of mastication are located at various depths in the parotid and infratemporal regions of the face. They attach to the mandible and receive their motor innervation from the mandibular division of the

trigeminal nerve (CN V₃). The muscles of the oral floor that aid in opening the mouth are found on in **Table 37.3** on **p. 516**.

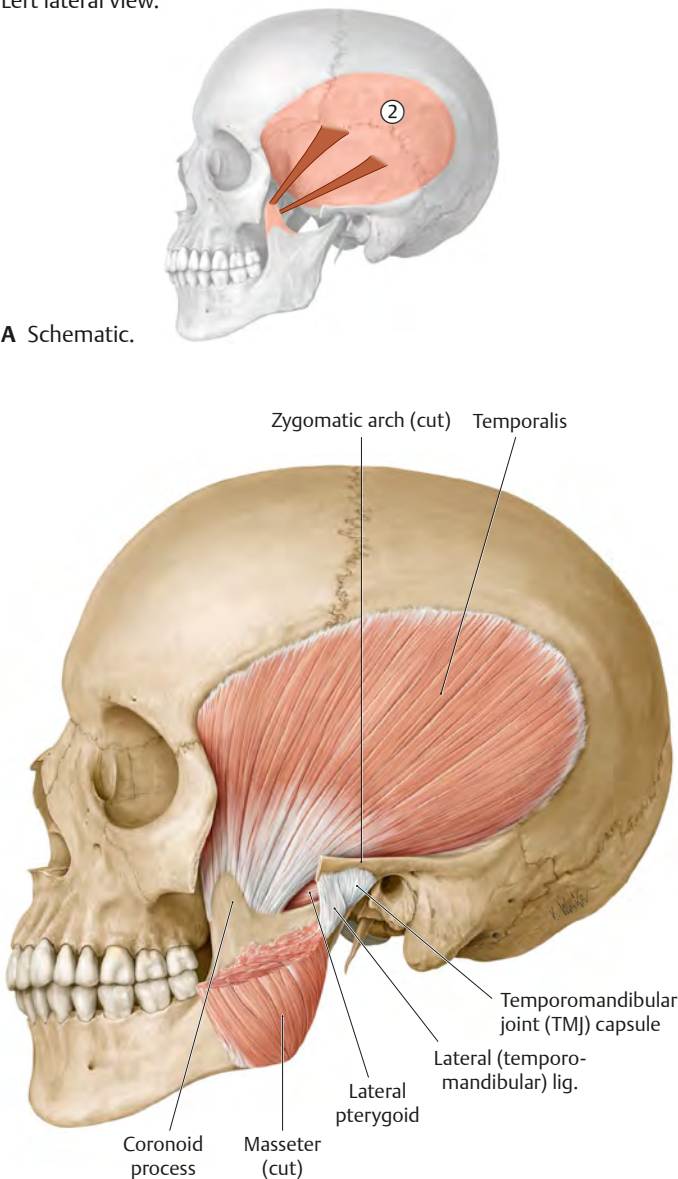
Table 39.3 Muscles of mastication: Masseter and temporalis				
Muscle	Origin	Insertion	Innervation	Action
① Masseter	Superficial layer: zygomatic arch (anterior two thirds) Deep layer: zygomatic arch (posterior one third)	Mandibular angle (masseteric tuberosity)	Mandibular n. (CN V ₃) via masseteric n.	Elevates (entire muscle) and protrudes (superficial fibers) the mandible
② Temporalis	Temporal fossa (inferior temporal line)	Coronoid process of mandible (apex and medial surface)	Mandibular n. (CN V ₃) via deep temporal nn.	<i>Vertical fibers:</i> Elevate mandible <i>Horizontal fibers:</i> Retract (retrude) mandible <i>Unilateral:</i> Lateral movement of mandible (chewing)

Fig. 39.11 Masseter muscle
Left lateral view.



B Masseter with temporalis muscle.

Fig. 39.12 Temporalis muscle
Left lateral view.



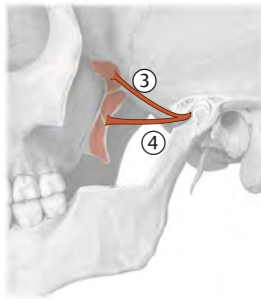
B Temporalis muscle. *Removed:* Masseter and zygomatic arch.

Table 39.4 Muscles of mastication: Pterygoid muscles

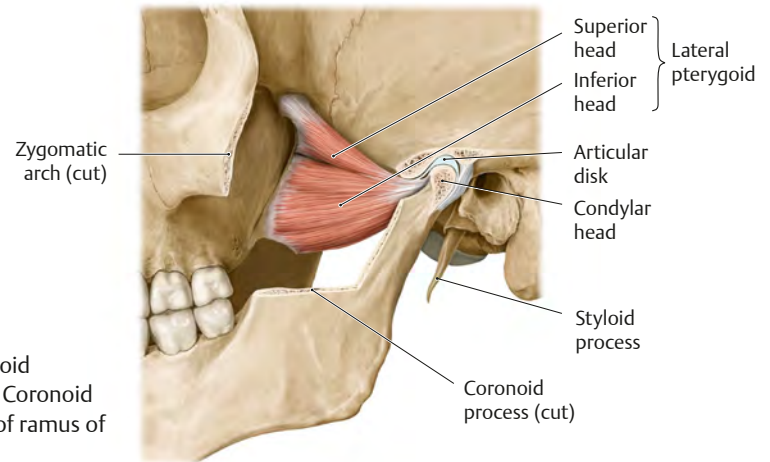
Muscle		Origin	Insertion	Innervation	Action
Lateral pterygoid	③ Superior head	Greater wing of sphenoid bone (infratemporal crest)	Temporomandibular joint (articular disk)	Mandibular n. (CN V ₃) via lateral pterygoid n.	<i>Bilateral</i> : Protrudes mandible (pulls articular disk forward) <i>Unilateral</i> : Lateral movements of mandible (chewing)
	④ Inferior head	Lateral pterygoid plate (lateral surface)	Mandible (condylar process)		
Medial pterygoid	⑤ Superficial head	Maxilla (tuberosity)	Pterygoid tuberosity on medial surface of the mandibular angle	Mandibular n. (CN V ₃) via medial pterygoid n.	<i>Bilateral</i> : Elevates mandible with masseter; contributes to protrusion. <i>Unilateral</i> : small grinding movements.
	⑥ Deep head	Medial surface of lateral pterygoid plate and pterygoid fossa			

Fig. 39.13 Lateral pterygoid muscle

Left lateral view.



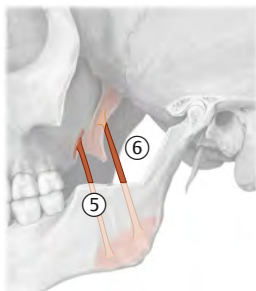
A Schematic.



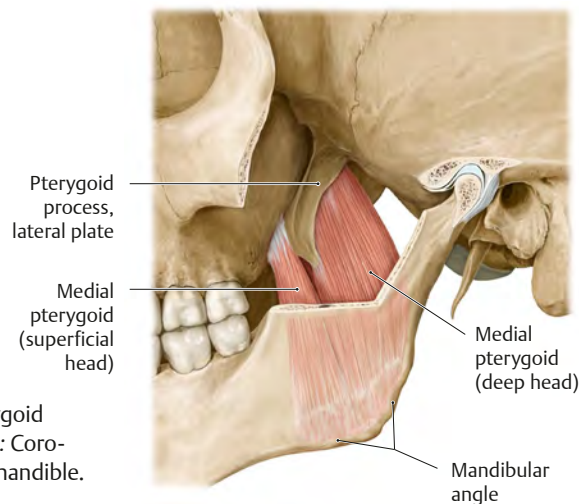
B Left lateral pterygoid muscle. *Removed*: Coronoid process and part of ramus of mandible.

Fig. 39.14 Medial pterygoid muscle

Left lateral view.



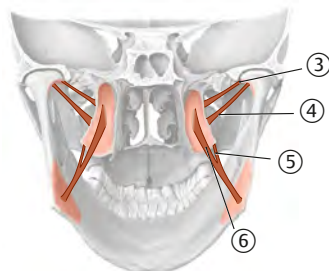
A Schematic.



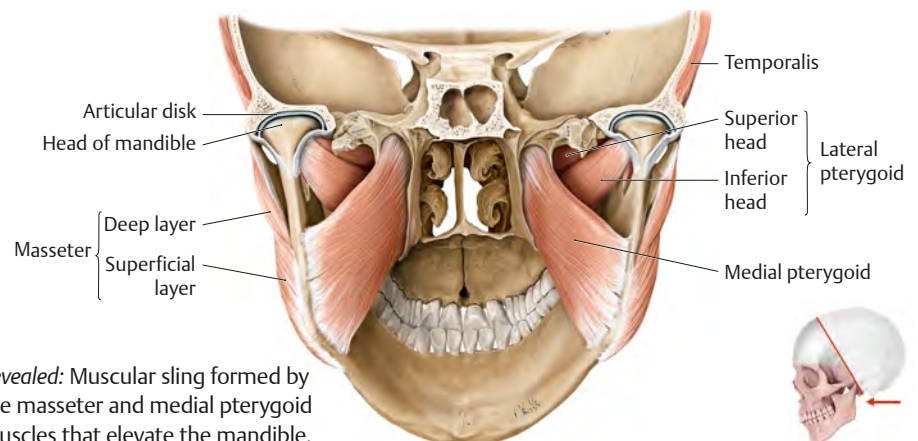
B Left medial pterygoid muscle. *Removed*: Coronoid process of mandible.

Fig. 39.15 Masticatory muscle sling

Oblique posterior view.



A Schematic.



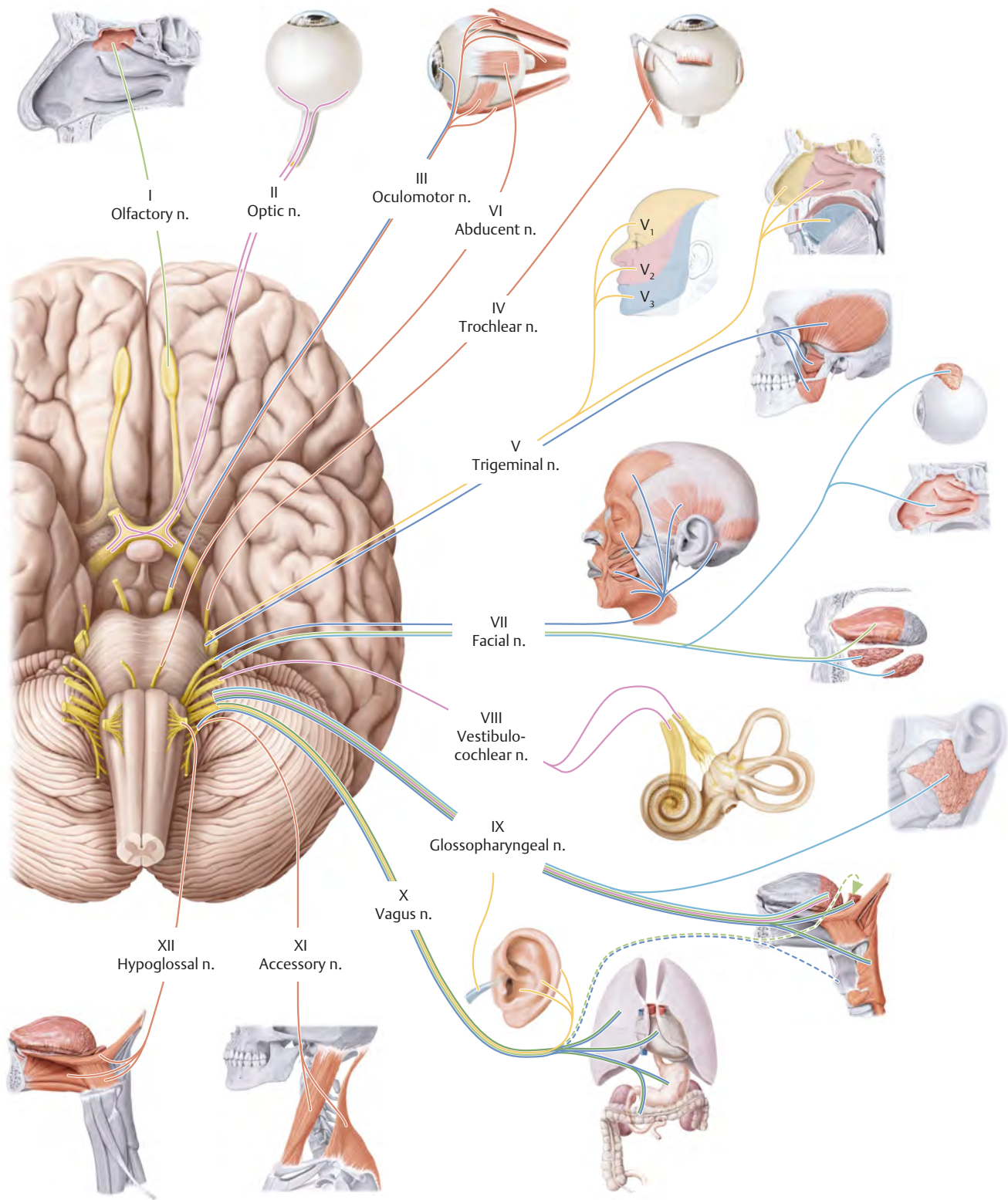
B *Revealed*: Muscular sling formed by the masseter and medial pterygoid muscles that elevate the mandible.

40 Cranial Nerves

Cranial Nerves: Overview

Fig. 40.1 Cranial nerves
 Inferior (basal) view. The 12 pairs of cranial nerves (CN) are numbered according to the order of their emergence from the brainstem. *Note:* The sensory and motor fibers of the cranial nerves enter and exit the

brainstem at the same sites (in contrast to spinal nerves, whose sensory and motor fibers enter and leave through posterior and anterior roots, respectively). For fiber color code, see **Table 40.1**.



The cranial nerves contain both afferent (sensory) and efferent (motor) axons that belong to either the somatic or the autonomic (visceral) nervous system (see pp. 694–695). The somatic fibers allow interaction with the environment, whereas the visceral fibers regulate the autonomic activity of internal organs. In addition to the general fiber types,

the cranial nerves may contain special fiber types associated with particular structures (e.g., auditory apparatus and taste buds). The cranial nerve fibers originate or terminate at specific nuclei, which are similarly classified as either general or special, somatic or visceral, and afferent or efferent.

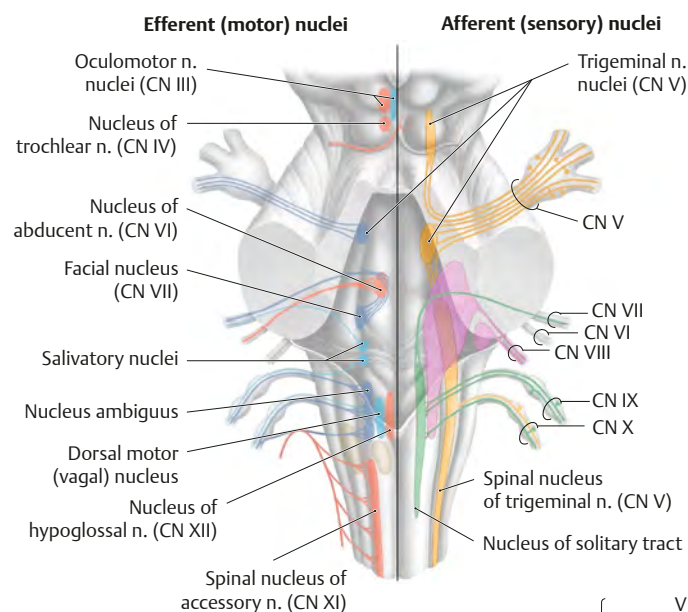
Table 40.1 Classification of cranial nerve fibers and nuclei

This color coding is used in subsequent chapters to indicate fiber and nuclei classifications.

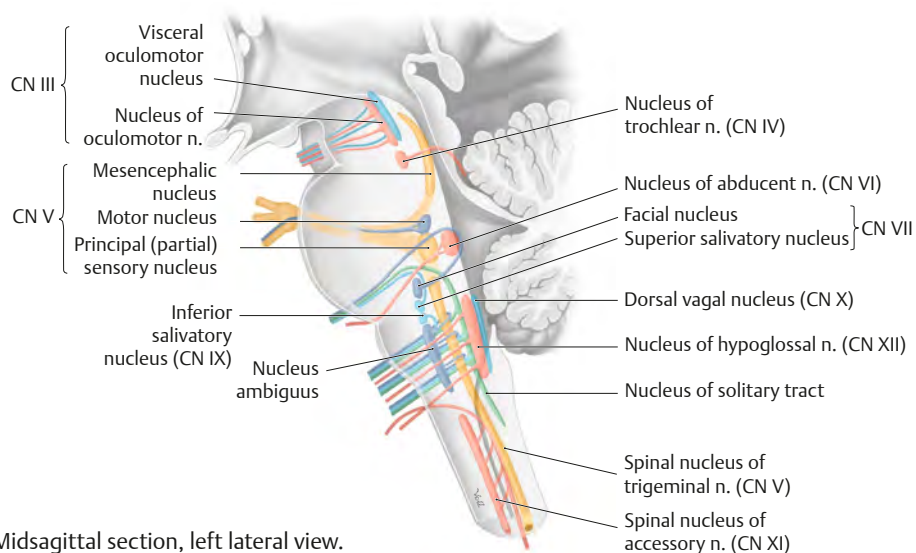
Fiber type	Example	Fiber type	Example
General somatic efferent (somatomotor function)	Innervate skeletal muscles	General somatic afferent (somatic sensation)	Conduct impulses from skin, skeletal muscle spindles
General visceral efferent (visceromotor function)	Innervate smooth muscle of the viscera, intraocular muscles, heart, salivary glands, etc.	Special somatic afferent	Conduct impulses from retina, auditory and vestibular apparatuses
Special visceral efferent	Innervate skeletal muscles derived from branchial arches	General visceral afferent (visceral sensation)	Conduct impulses from viscera, blood vessels
		Special visceral afferent	Conduct impulses from taste buds, olfactory mucosa

Fig. 40.2 Cranial nerve nuclei

The sensory and motor fibers of cranial nerves III to XII originate and terminate in the brainstem at specific nuclei.



A Posterior view with the cerebellum removed.



B Midsagittal section, left lateral view.

Table 40.2 Cranial nerves

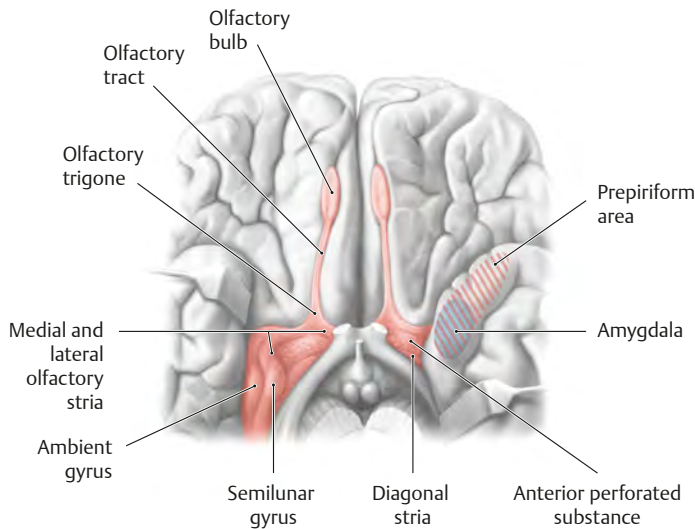
Cranial nerve	Origin	Functional fiber types
CN I: Olfactory n.	Telencephalon*	●
CN II: Optic n.	Diencephalon*	●
CN III: Oculomotor n.	Mesencephalon	● ● ● ● ●
CN IV: Trochlear n.		● ● ● ● ●
CN V: Trigeminal n.		● ● ● ● ●
CN VI: Abducent n.	Pons	● ● ● ● ●
CN VII: Facial n.		● ● ● ● ●
CN VIII: Vestibulocochlear n.		● ● ● ● ●
CN IX: Glossopharyngeal n.		● ● ● ● ●
CN X: Vagus n.	Medulla oblongata	● ● ● ● ●
CN XI: Accessory n.		● ● ● ● ●
CN XII: Hypoglossal n.		● ● ● ● ●

* The olfactory and optic nerves are extensions of the brain rather than true nerves; they are therefore not associated with nuclei in the brainstem.

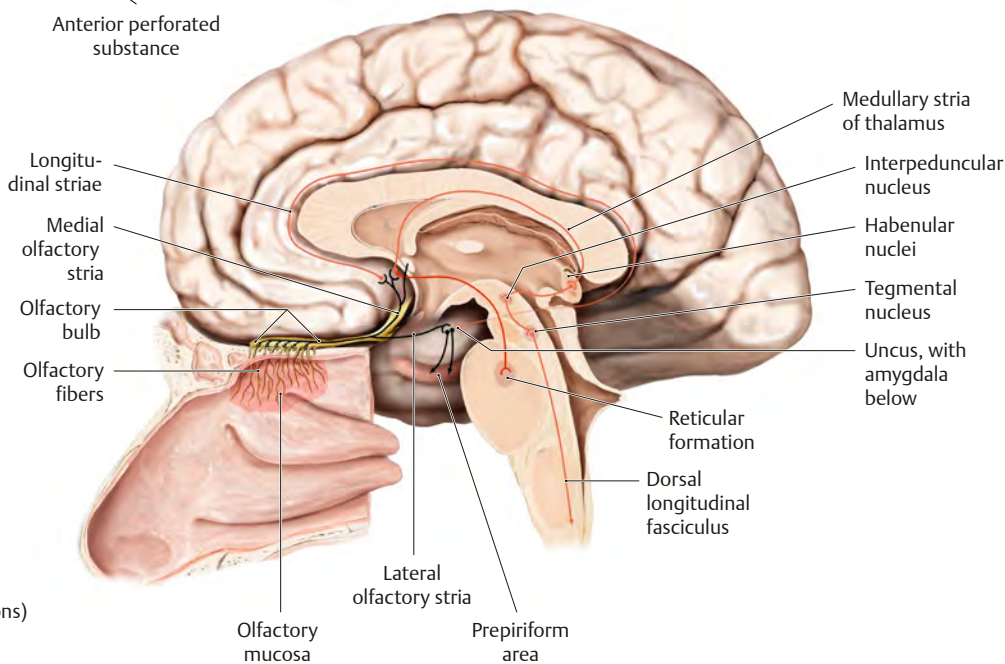
CN I & II: Olfactory & Optic Nerves

The olfactory and optic nerves are not true peripheral nerves but extensions (tracts) of the telencephalon and diencephalon, respectively.

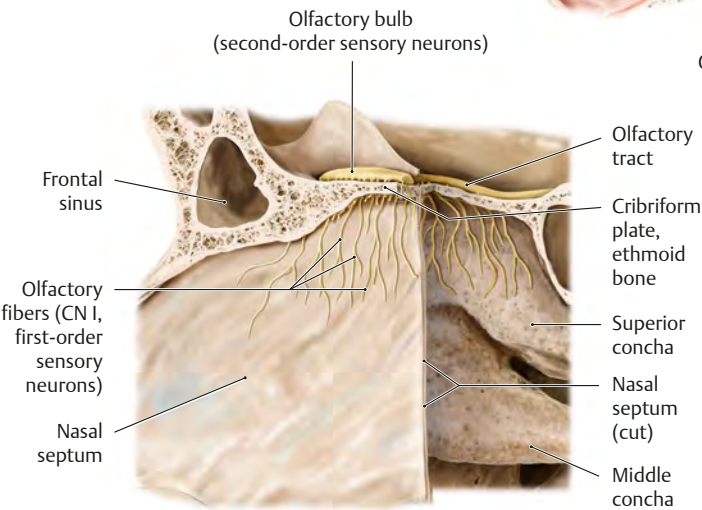
They are therefore not associated with cranial nerve nuclei in the brainstem.



A Olfactory bulb and tract, inferior view.
Note: The amygdala and prepiriform area are deep to the basal surface of the brain.



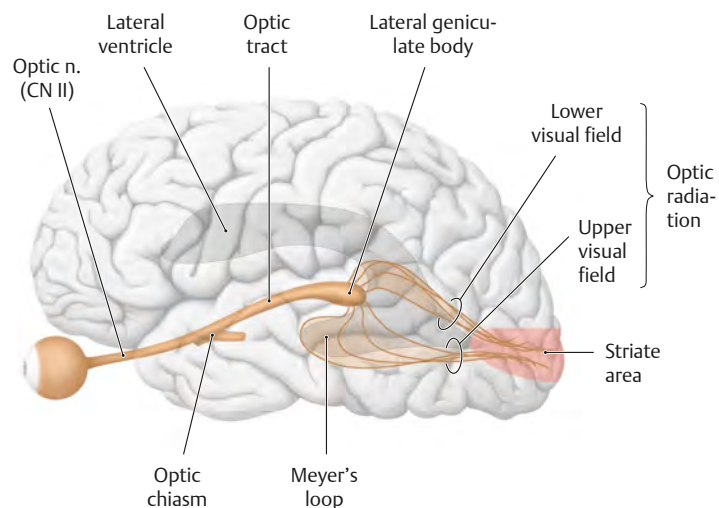
B Course of the olfactory nerve. Parasagittal section, viewed from left side.



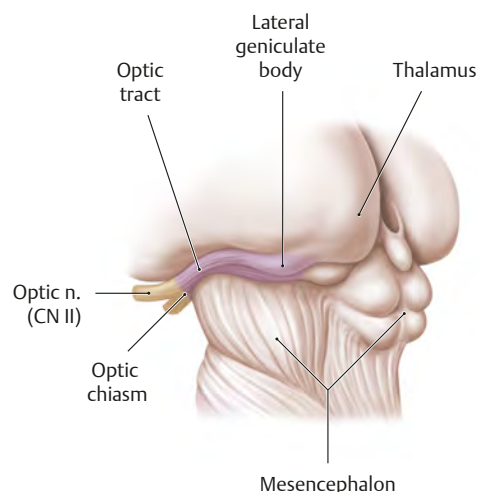
C Olfactory fibers. Portion of left nasal septum and lateral wall of right nasal cavity, left lateral view.

Fig. 40.4 Optic nerve (CN II)

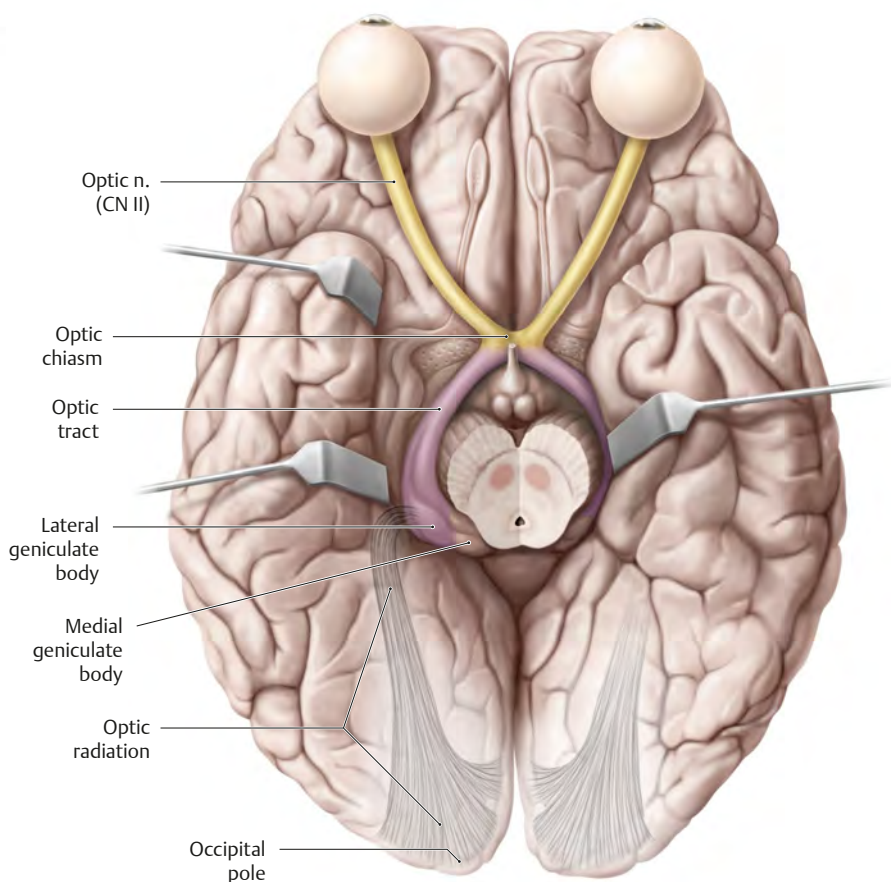
The optic nerve passes from the eyeball through the optic canal into the middle cranial fossa. The two optic nerves join below the base of the diencephalon to form the optic chiasm, before dividing into the two optic tracts. Each of these tracts divides into a lateral and medial root. Many retinal cell ganglion axons cross the midline to the contralateral side of the brain in the optic chiasm.



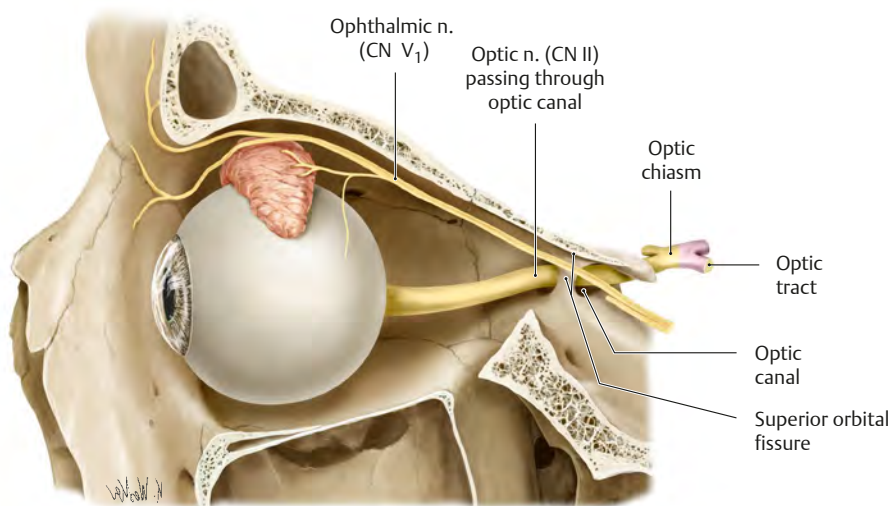
A Optic nerve in the geniculate visual pathway, left lateral view.



B Termination of the optic tract, left postero-lateral view of the brainstem. The optic nerve contains the axons of retinal ganglion cells, which terminate mainly in the lateral geniculate body of the diencephalon and in the mesencephalon (superior colliculus).



C Course of the optic nerve, inferior (basal) view.



D Optic nerve in the left orbit, lateral view. The optic nerve exits the orbit via the optic canal. *Note:* The other cranial nerves (III, IV, V1, and VI) entering the orbit do so via the superior orbital fissure.

CN III, IV & VI: Oculomotor, Trochlear & Abducent Nerves

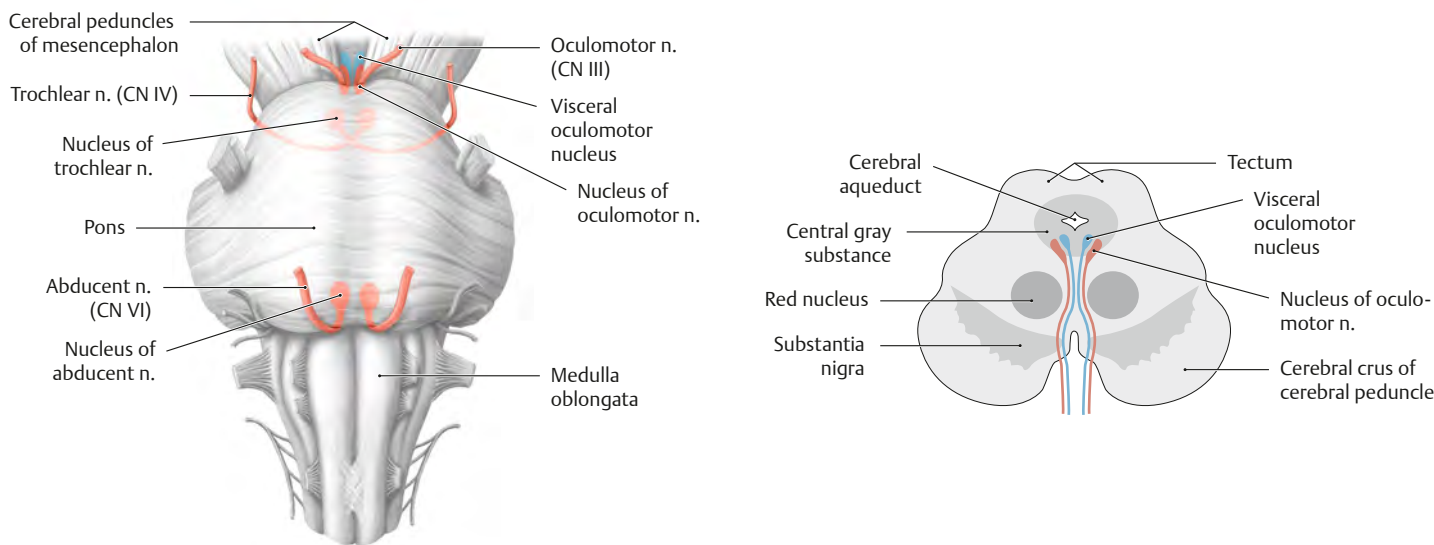
Cranial nerves III, IV, and VI innervate the extraocular muscles (see p. 605). Of the three, only the oculomotor nerve (CN III) contains both somatic and visceral efferent fibers; it is also the only cranial nerve of

the extraocular muscles to innervate multiple extra- and intraocular muscles.

Fig. 40.5 Nuclei of the oculomotor, trochlear, and abducent nerves

The trochlear nerve (CN IV) is the only cranial nerve in which all the fibers cross to the opposite side. It is also the only cranial nerve to

emerge from the dorsal side of the brainstem and, consequently, has the longest intradural (intracranial) course of any cranial nerve.



A Emergence of the cranial nerves of the extraocular muscles. Anterior view of the brainstem.

B Oculomotor nerve nuclei. Transverse section, superior view.

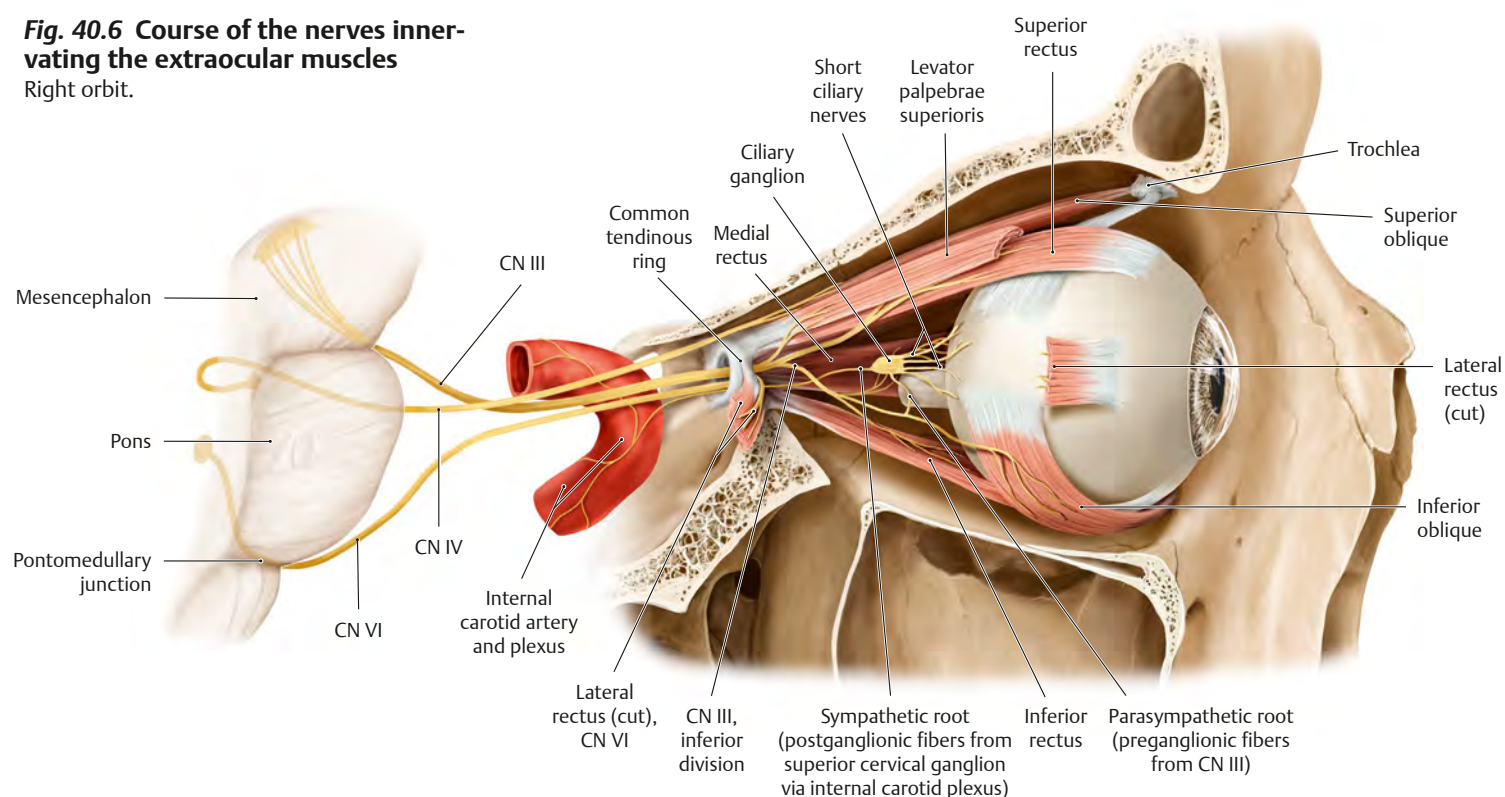
Table 40.3 Cranial nerves of the extraocular muscles				
Course*	Fibers	Nuclei	Function	Effects of nerve injury
Oculomotor nerve (CN III)				
Runs anteriorly from mesencephalon	Somatic efferent	Oculomotor nucleus	Innervates: - Levator palpebrae superioris - Superior, medial, and inferior rectus - Inferior oblique	Complete oculomotor palsy (paralysis of extra- and intraocular muscles): - Ptosis (drooping of eyelid) - Downward and lateral gaze deviation - Diplopia (double vision) - Mydriasis (pupil dilation) - Accommodation difficulties (ciliary paralysis)
	Visceral efferent	Visceral oculomotor (Edinger-Westphal) nucleus	Synapse with neurons in ciliary ganglia. Innervates: - Pupillary sphincter - Ciliary muscle	
Trochlear nerve (CN IV)				
Emerges from posterior surface of brainstem near midline, courses anteriorly around the cerebral peduncle	Somatic efferent	Nucleus of the trochlear n.	Innervates: Superior oblique	- Diplopia - Affected eye is higher and deviated medially (dominance of inferior oblique)
Abducent nerve (CN VI)				
Follows a long extradural path**	Somatic efferent	Nucleus of the abducent n.	Innervates: Lateral rectus	- Diplopia - Medial strabismus (sp.) (due to unopposed action of medial rectus)
* All three nerves enter the orbit through the superior orbital fissure; CN III and CN VI pass through the common tendinous ring of the extraocular muscles.				
** The abducent nerve follows an extradural course; abducent nerve palsy may therefore develop in association with meningitis and subarachnoid hemorrhage.				

Note: The oculomotor nerve supplies parasympathetic innervation to the intraocular muscles and somatic motor innervation to most of the extraocular muscles (also the levator palpebrae superioris). Its

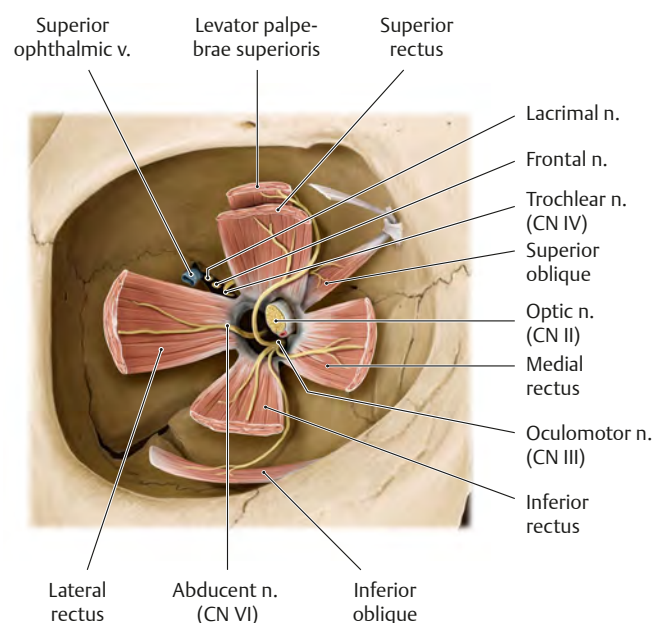
parasympathetic fibers synapse in the ciliary ganglion. Oculomotor nerve palsy may affect exclusively the parasympathetic or somatic fibers, or both concurrently.

Fig. 40.6 Course of the nerves innervating the extraocular muscles

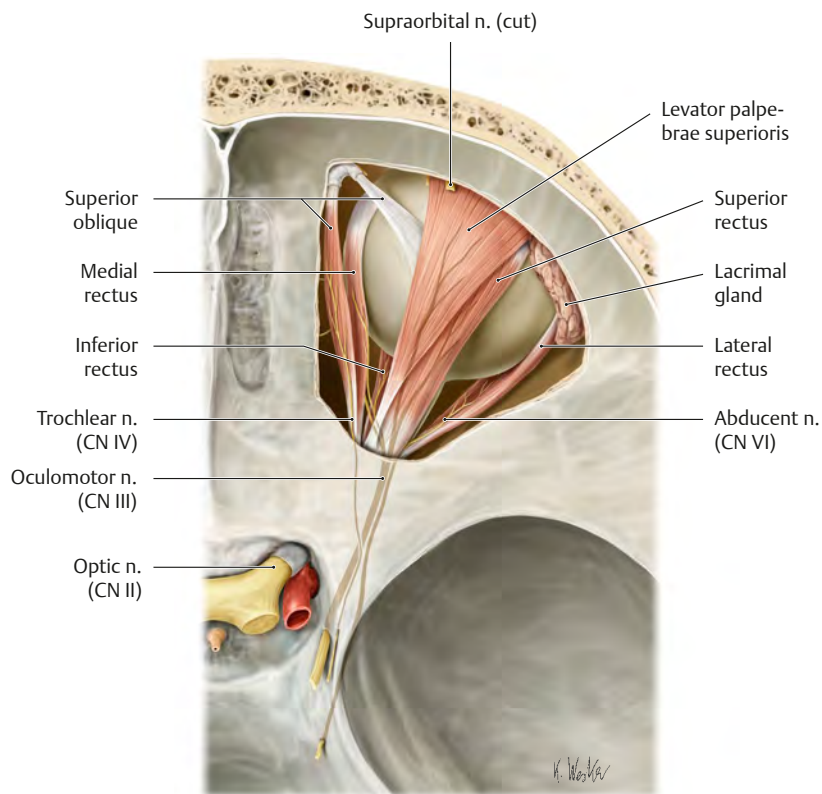
Right orbit.



A Lateral view.



B Anterior view. CN II exits the orbit via the optic canal, which lies medial to the superior orbital fissure (site of emergence of CN III, IV, and VI).



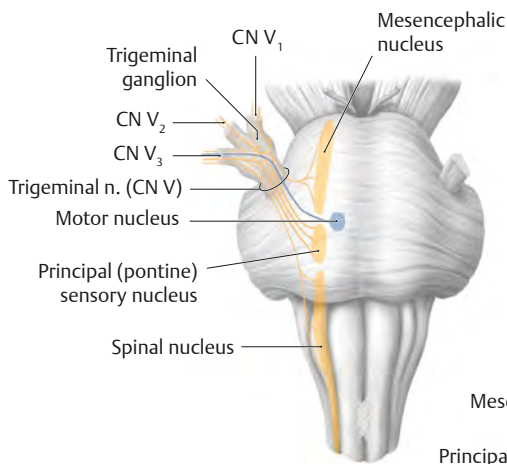
C Superior view of the opened orbit. Note the relationship between the optic canal and the superior orbital fissure.

CN V: Trigeminal Nerve

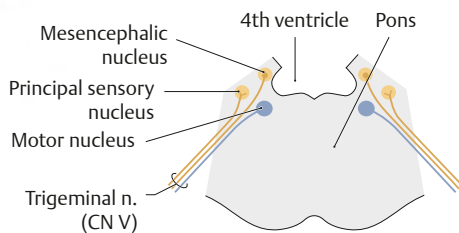
The trigeminal nerve, the sensory nerve of the head, has three somatic afferent nuclei: the mesencephalic nucleus, which receives proprioceptive fibers from the muscles of mastication; the principal (pontine)

sensory nucleus, which chiefly mediates touch; and the spinal nucleus, which mediates pain and temperature sensation. The motor nucleus supplies motor innervation to the muscles of mastication.

Fig. 40.7 Trigeminal nerve nuclei



A Anterior view of the brainstem.



B Cross section through the pons, superior view.

Fig. 40.8 Divisions of the trigeminal nerve (CN V)
Right lateral view.

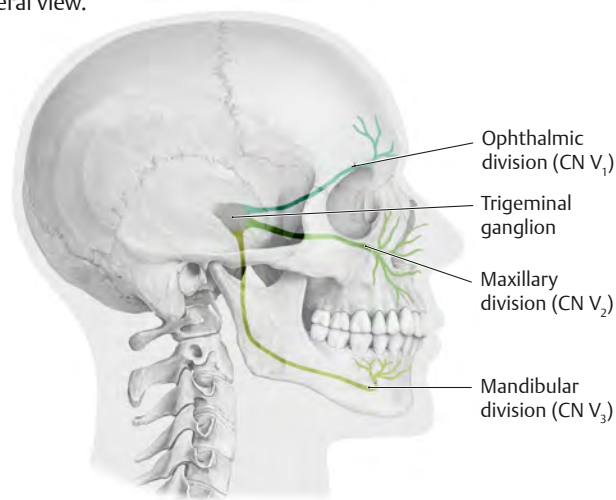
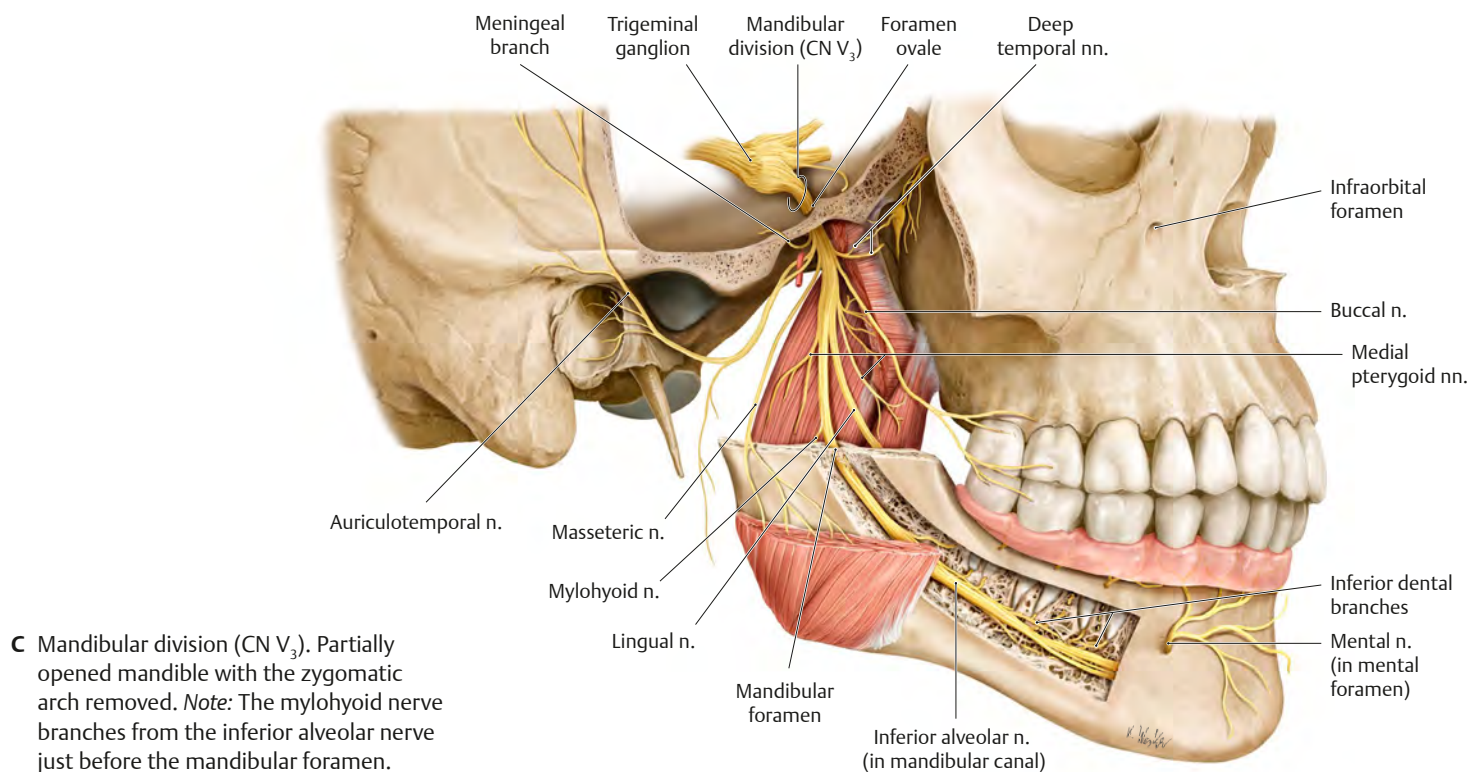
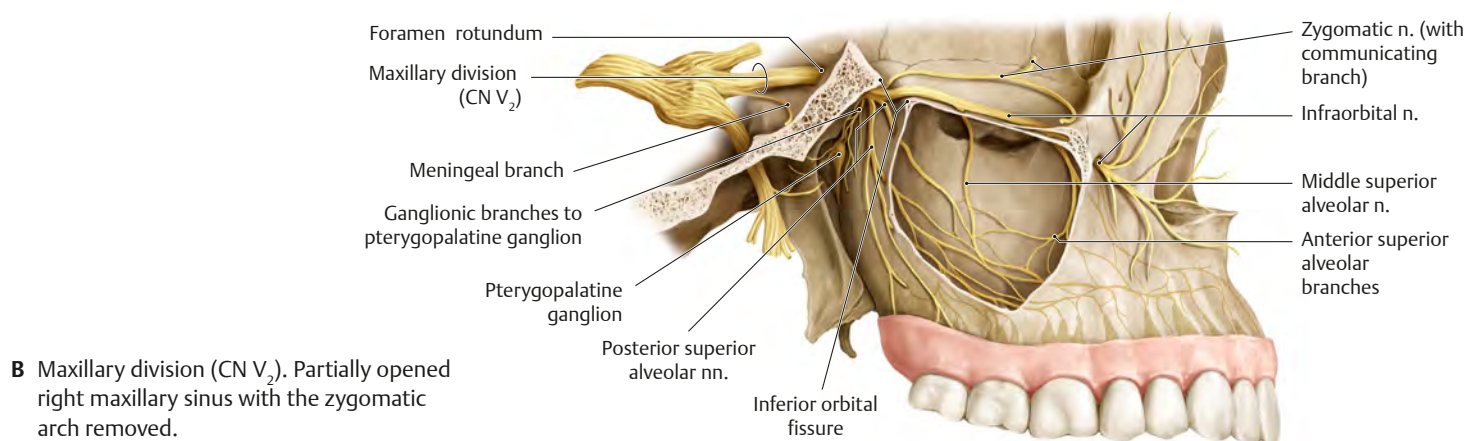
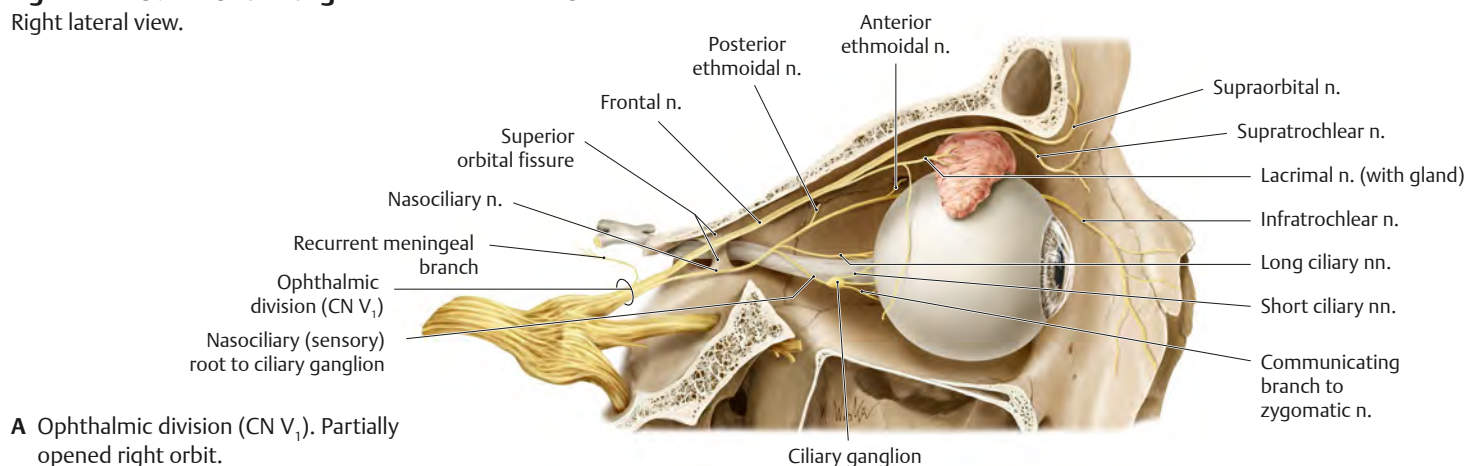


Table 40.4 Trigeminal nerve (CN V)				
Course	Fibers	Nuclei	Function	Effects of nerve injury
Exits from the middle cranial fossa.	Somatic afferent	- Principal (pontine) sensory nucleus of the trigeminal n. - Mesencephalic nucleus of the trigeminal n. - Spinal nucleus of the trigeminal n.	Innervates: - Facial skin (A) - Nasopharyngeal mucosa (B) - Tongue (anterior two thirds) (C) Involved in the corneal reflex (reflex closure of eyelid)	- Sensory loss (traumatic nerve lesions) - Herpes zoster ophthalmicus (varicella-zoster virus); herpes zoster of the face
Ophthalmic division (CN V₁): Enters orbit through superior orbital fissure	Special visceral efferent	Motor nucleus of the trigeminal n.	Innervates (via CN V ₃): - Muscles of mastication (temporalis, masseter, medial and lateral pterygoids (D)) - Oral floor muscles (mylohyoid, anterior digastric) - Tensor tympani - Tensor veli palatini	
Maxillary division (CN V₂): Enters pterygopalatine fossa through foramen rotundum	Visceral efferent pathway*	- Lacrimal n. (CN V₁) conveys parasympathetic fibers from CN VII along the zygomatic n. (CN V₂) to the lacrimal gland - Lingual n. (CN V₃) conveys parasympathetic fibers from CN VII (via the chorda tympani) to the submandibular and sublingual glands - Auriculotemporal n. (CN V₃) conveys parasympathetic fibers from CN IX to the parotid gland		
Mandibular division (CN V₃): Passes through foramen ovale into infratemporal fossa	Visceral afferent pathway*	Gustatory (taste) fibers from CN VII (via chorda tympani) travel with the lingual n. (CN V ₃) to the anterior two thirds of the tongue		

* Fibers of certain cranial nerves adhere to divisions or branches of the trigeminal nerve, by which they travel to their destination.
** All three divisions contribute to dural innervation in the anterior and middle cranial fossae.

Fig. 40.9 Course of the trigeminal nerve divisions

Right lateral view.

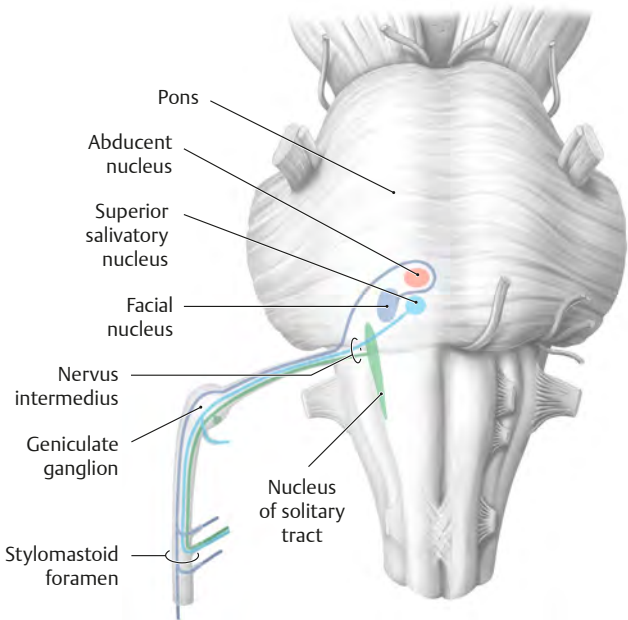


CN VII: Facial Nerve

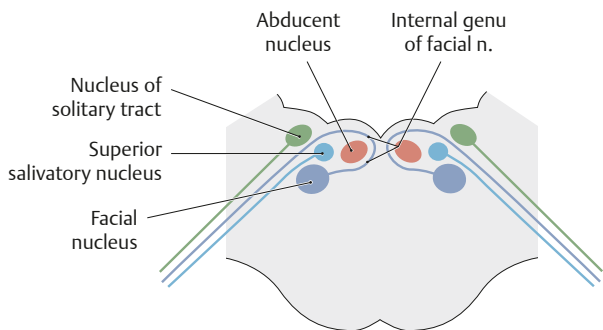
The facial nerve mainly conveys special visceral efferent (branchiogenic) fibers from the facial nerve nucleus to the muscles of facial expression. The other visceral efferent (parasympathetic) fibers from the superior

salivatory nucleus are grouped with the visceral afferent (gustatory) fibers to form the nervus intermedius.

Fig. 40.10 Facial nerve nuclei

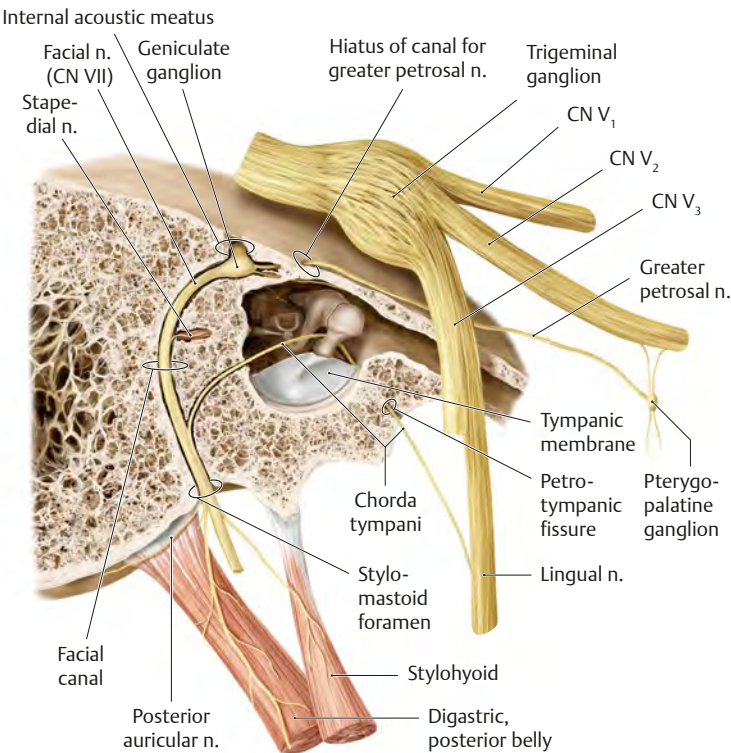


A Anterior view of the brainstem.

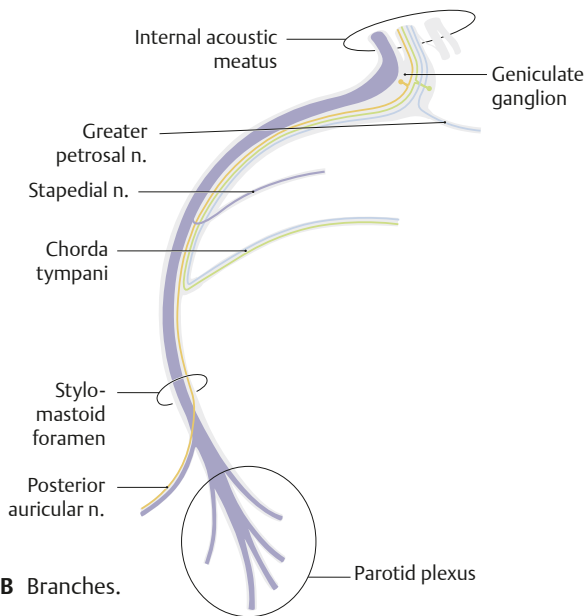


B Cross section through the pons, superior view.

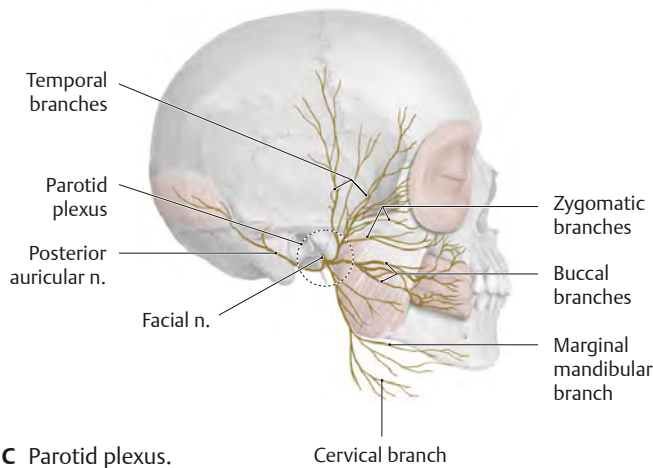
Fig. 40.11 Branches of the facial nerve
Right lateral view.



A Facial nerve in the temporal bone.



B Branches.



C Parotid plexus.

Table 40.5

Facial nerve (CN VII)

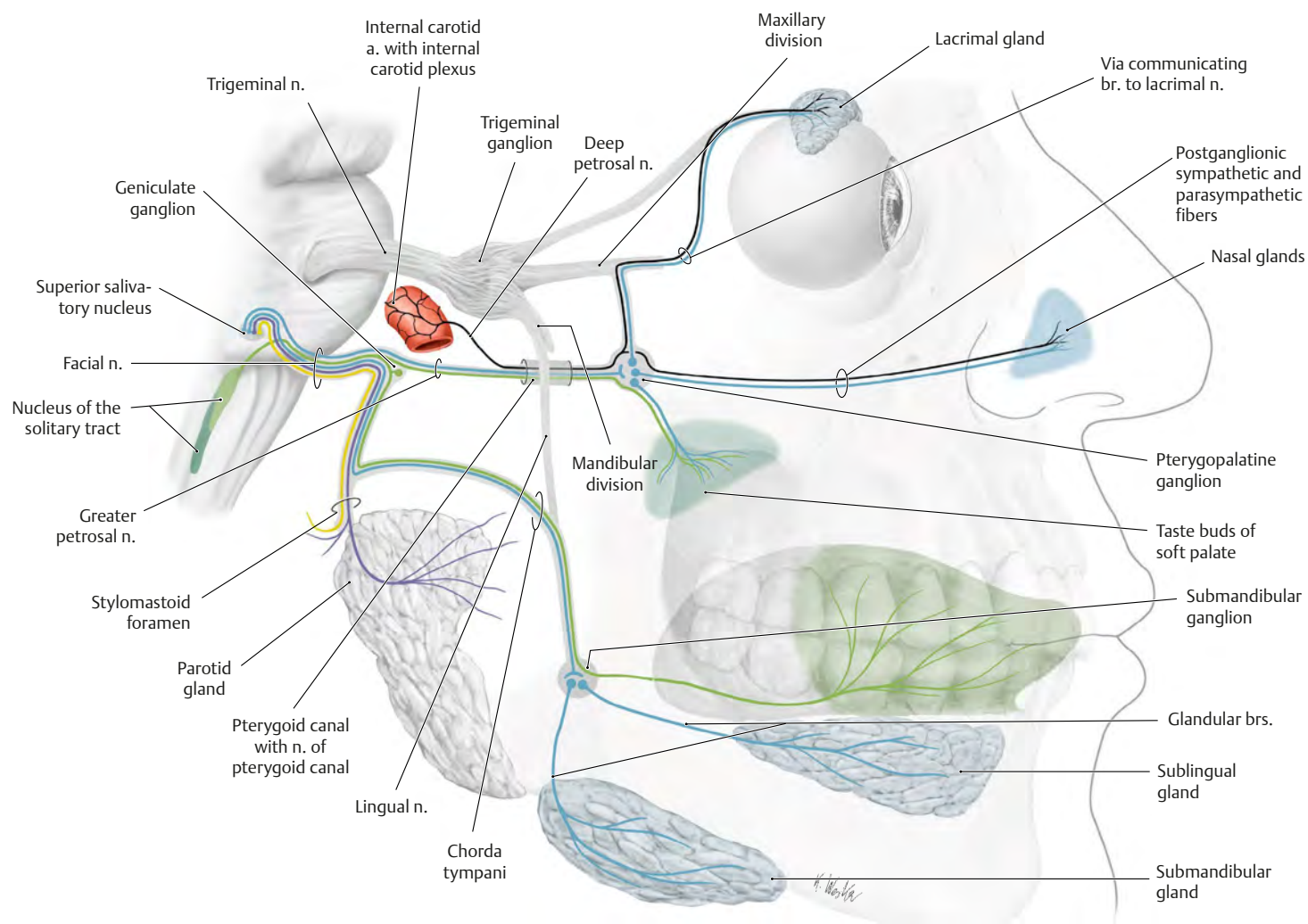
Course	Fibers	Nuclei	Function	Effects of nerve injury
Emerges in the cerebellopontine angle between the pons and olive; passes through the internal acoustic meatus into the temporal bone (petrous part), where it divides into: • Greater petrosal n. • Stapedial n. • Chorda tympani Certain special visceral efferent fibers pass through the stylomastoid foramen to the skull base, forming the intraparotid plexus	Special visceral efferent	Facial nucleus	Innervate: • Muscles of facial expression • Stylohyoid • Digastric (posterior belly) • Stapedius	Peripheral facial nerve injury: paralysis of muscles of facial expression on affected side
	Visceral efferent (parasympathetic)*	Superior salivatory nucleus	Synapse with neurons in the pterygopalatine or submandibular ganglion. Innervate: • Lacrimal gland • Small glands of nasal mucosa, hard and soft palate • Submandibular gland • Sublingual gland • Small salivary glands of tongue (dorsum)	Associated disturbances of taste, lacrimation, salivation, hyperacusis, etc.
	Special visceral afferent*	Nucleus of the solitary tract	Peripheral processes of fibers from geniculate ganglion form the chorda tympani (gustatory fibers from tongue)	
	Somatic afferent		Sensory fibers from the auricle, skin of the auditory canal, and outer surface of the tympanic membrane travel via CN VII to the principal sensory nucleus of the trigeminal n.	

* Grouped to form nervus intermedius, which aggregates with the visceral efferent fibers from the facial n. nucleus.

Fig. 40.12 Course of the facial nerve

Right lateral view. This figure shows the distribution of all the fiber types in Table 40.5. Visceral efferent (parasympathetic) and special

visceral afferent (taste) fibers shown in blue and green respectively. Postganglionic sympathetic fibers are shown in black.

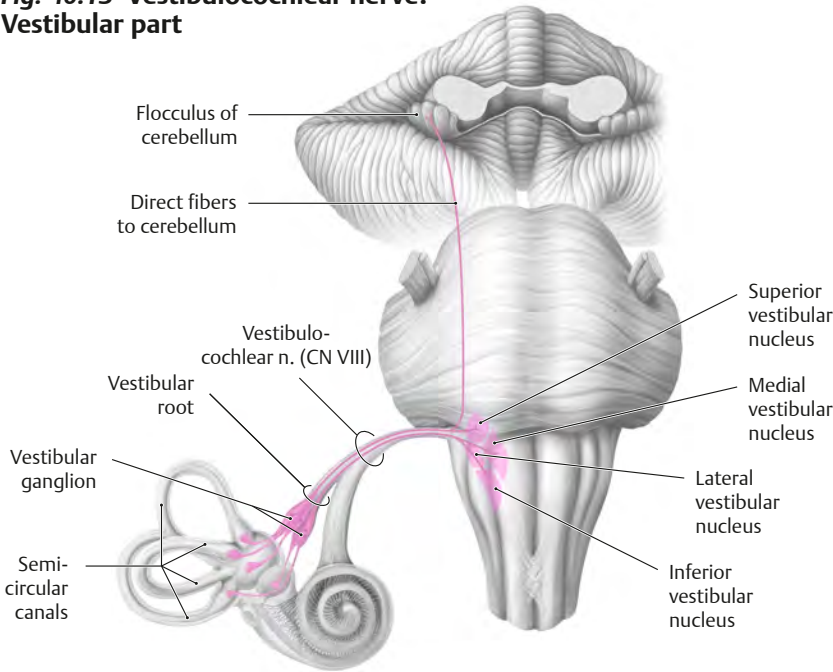


CN VIII: Vestibulocochlear Nerve

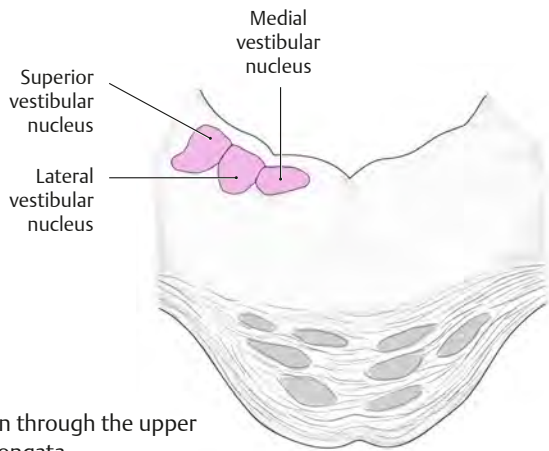
The vestibulocochlear nerve is a special somatic afferent nerve that consists of two roots. The vestibular root transmits impulses from the

vestibular apparatus; the cochlear root transmits impulses from the auditory apparatus.

Fig. 40.13 Vestibulocochlear nerve: Vestibular part

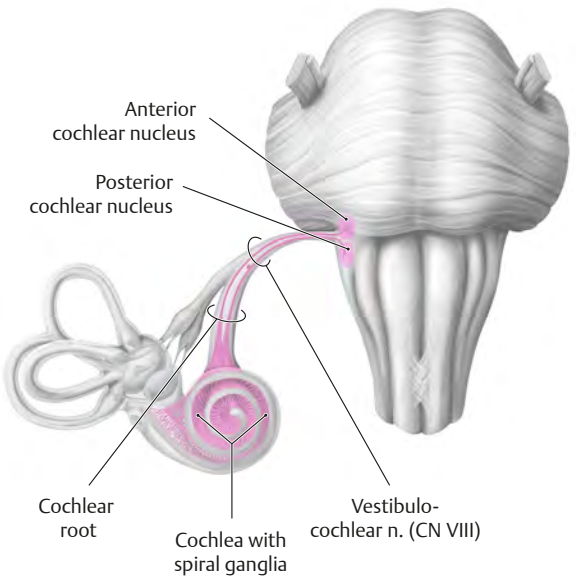


A Anterior view of the medulla oblongata and pons with cerebellum.

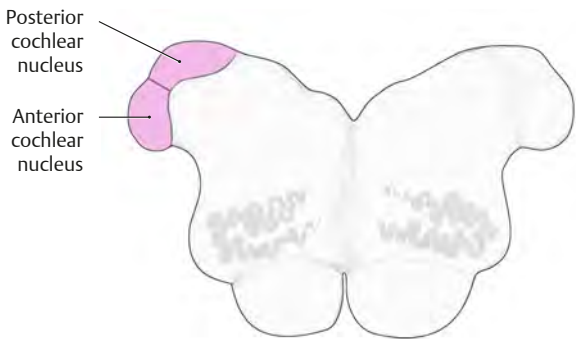


B Cross section through the upper medulla oblongata.

Fig. 40.14 Vestibulocochlear nerve: Cochlear part



A Anterior view of the medulla oblongata and pons.



B Cross section through the upper medulla oblongata.

Table 40.6 Vestibulocochlear nerve (CN VIII)						
Part	Course	Fibers	Nuclei	Function	Effects of nerve injury	
Vestibular part	Pass from the inner ear through the internal acoustic meatus to the cerebellopontine angle, where they enter the brain	Special somatic afferent	Superior, lateral, medial, and inferior vestibular nuclei	Peripheral processes from the semicircular canals, saccule, and utricle pass to the vestibular ganglion and then to the four vestibular nuclei	Dizziness	
Cochlear part			Anterior and posterior cochlear nuclei	Peripheral processes beginning at the hair cells of the organ of Corti pass to the spiral ganglion and then to the two cochlear nuclei	Hearing loss	

Fig. 40.15 Vestibular and cochlear (spiral) ganglia

Note: The vestibular and cochlear roots are still separate structures in the petrous part of the temporal bone.

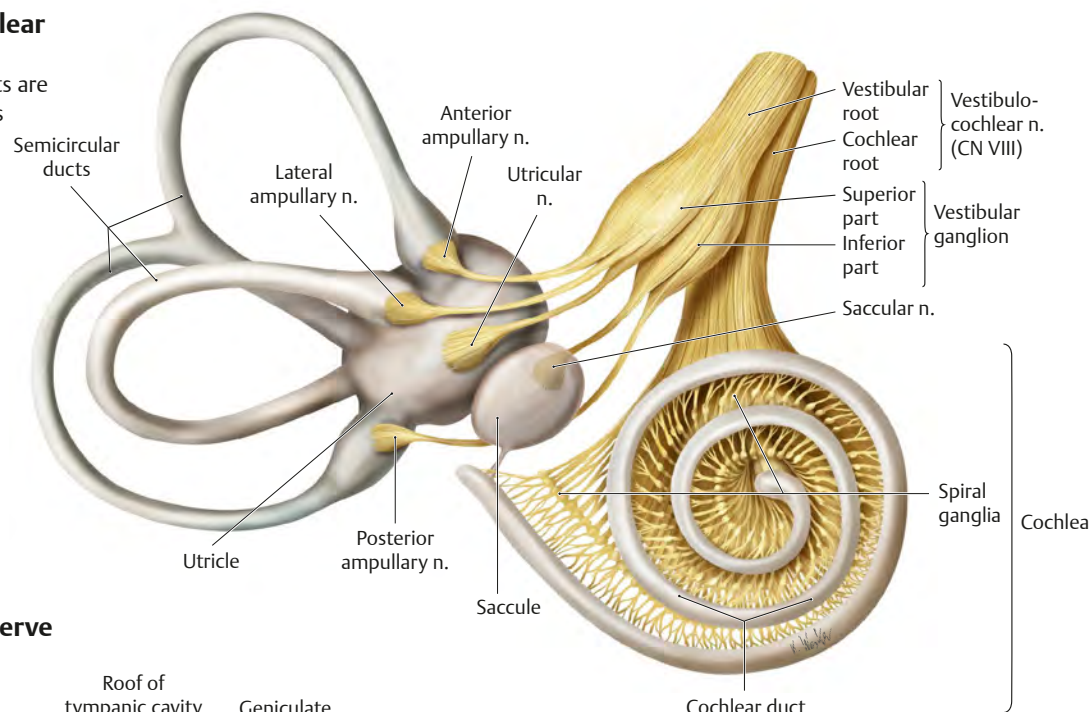
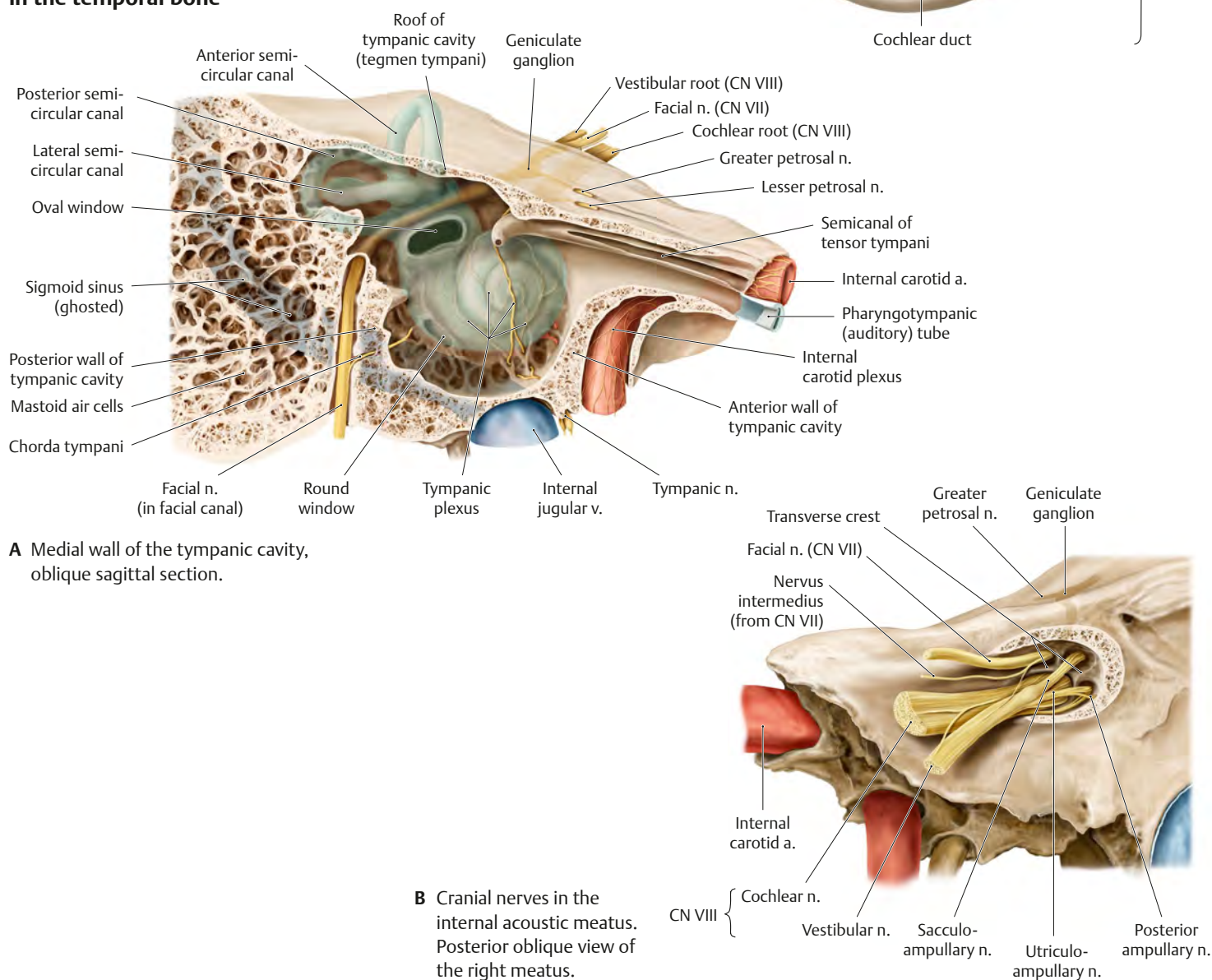
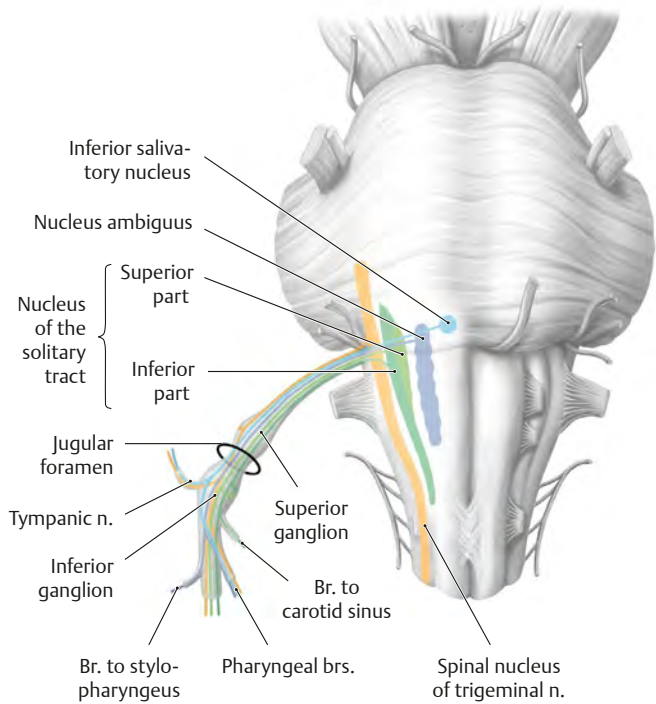


Fig. 40.16 Vestibulocochlear nerve in the temporal bone

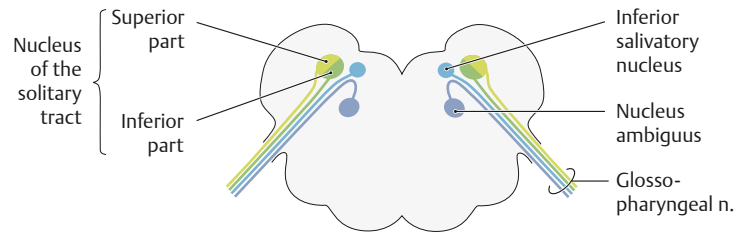


CN IX: Glossopharyngeal Nerve

Fig. 40.17 Glossopharyngeal nerve nuclei



A Anterior view of the medulla oblongata.



B Cross section through the medulla oblongata, superior view. *Not shown:* Nuclei of the trigeminal nerve.

Fig. 40.18 Course of the glossopharyngeal nerve

Left lateral view. *Note:* Fibers from the vagus nerve (CN X) combine with fibers from the glossopharyngeal nerve (CN IX) to form the pharyngeal plexus and supply the carotid sinus.

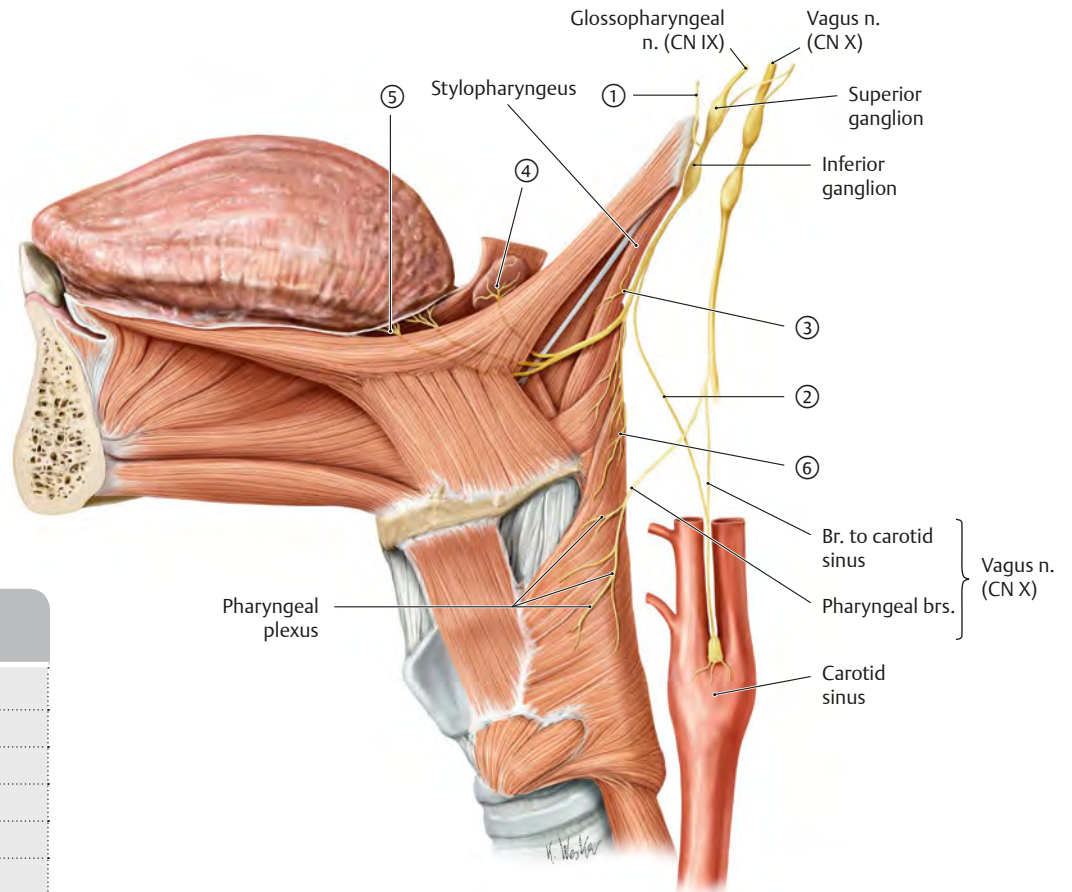


Table 40.7		Glossopharyngeal nerve branches
①	Tympanic n.	
②	Br. to carotid sinus	
③	Br. to stylopharyngeus muscle	
④	Tonsillar brs.	
⑤	Lingual brs.	
⑥	Pharyngeal brs.	

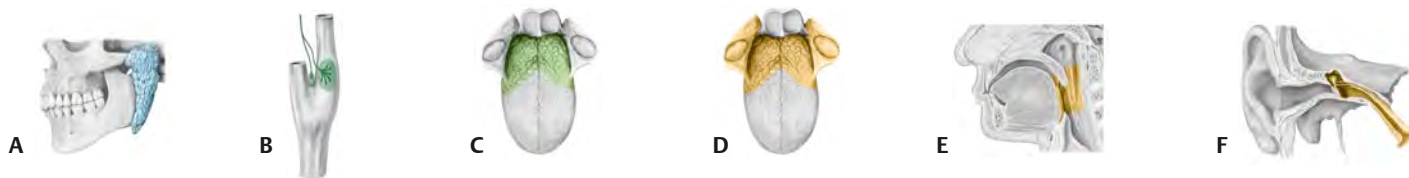


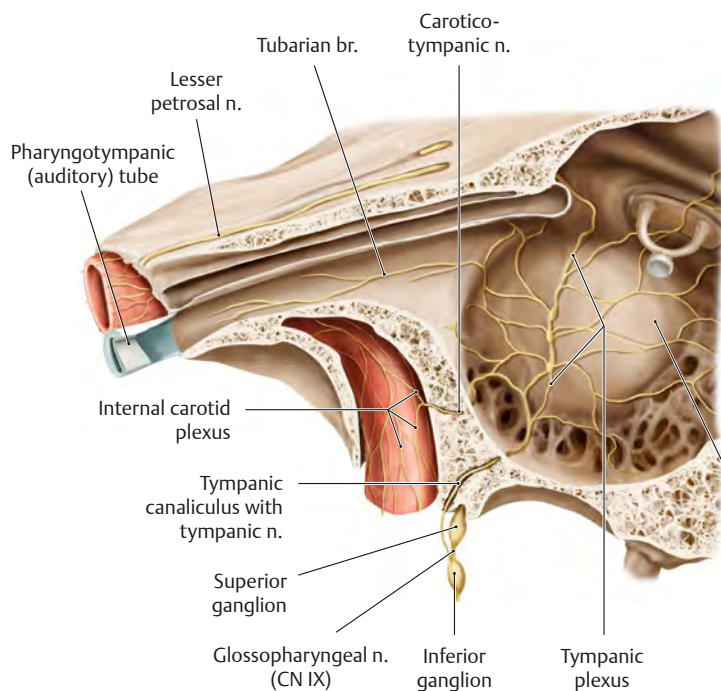
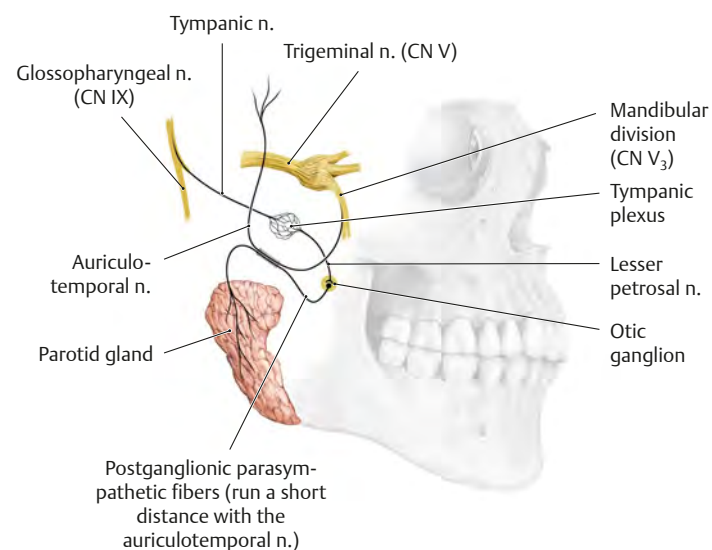
Table 40.8

Glossopharyngeal nerve (CN IX)

Course	Fibers	Nuclei	Function	Effects of nerve injury
Emerges from the medulla oblongata; leaves cranial cavity through the jugular foramen	Visceral efferent (parasympathetic)	Inferior salivatory nucleus	Parasympathetic presynaptic fibers are sent to the otic ganglion; postsynaptic fibers are distributed to • Parotid gland (A) • Buccal gland • Labial gland	Isolated lesions of CN IX are rare. Lesions are generally accompanied by lesions of CN X and CN XI (cranial part), as all three emerge jointly from the jugular foramen and are susceptible to injury in basal skull fractures.
	Special visceral efferent (branchiogenic)	Nucleus ambiguus	Innervate: • Constrictor muscles of the pharynx (pharyngeal branches join with the vagus nerve to form the pharyngeal plexus) • Stylopharyngeus	
	Visceral afferent	Nucleus of the solitary tract (inferior part)	Receive sensory information from • Chemoreceptors in the carotid body (B) • Pressure receptors in the carotid sinus	
	Special visceral afferent	Nucleus of the solitary tract (superior part)	Receives sensory information from the posterior third of the tongue (via the inferior ganglion) (C)	
	Somatic afferent	Spinal nucleus of trigeminal nerve	Peripheral processes of the intracranial superior ganglion or the extracranial inferior ganglion arise from • Tongue, soft palate, pharyngeal mucosa, and tonsils (D, E) • Mucosa of the tympanic cavity, internal surface of the tympanic membrane, pharyngotympanic tube (tympanic plexus) (F) • Skin of the external ear and auditory canal (blends with the vagus n.)	

Fig. 40.19 Glossopharyngeal nerve in the tympanic cavity

Left anterolateral view. The tympanic nerve contains visceral efferent (presynaptic parasympathetic) fibers for the otic ganglion, as well as somatic afferent fibers for the tympanic cavity and pharyngotympanic tube. It joins with sympathetic fibers from the internal carotid plexus (via the caroticotympanic nerve) to form the tympanic plexus.

**Fig. 40.20 Visceral efferent (parasympathetic) fibers of CN IX**

CN X: Vagus Nerve

Fig. 40.21 Vagus nerve nuclei

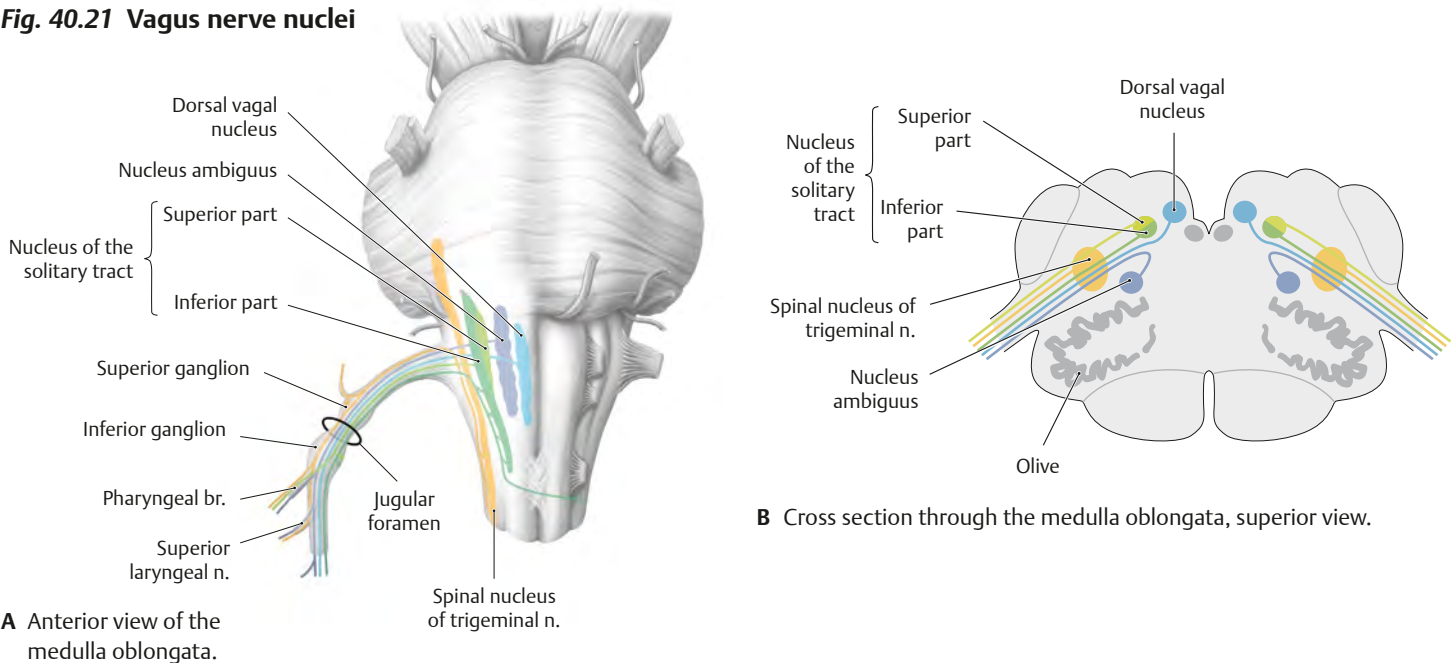


Table 40.9 Vagus nerve (CN X)				
Course	Fibers	Nuclei	Function	Effects of nerve injury
Emerges from the medulla oblongata; leaves the cranial cavity through the jugular foramen. CN X has the most extensive distribution of all the cranial nerves (vagus = “vagabond”), consisting of cranial, cervical, thoracic (see p. 87), and abdominal (see p. 215) parts.	Special visceral efferent (branchio-genic)	Nucleus ambiguus	Innervate: • Pharyngeal muscles (via pharyngeal plexus with CN IX) • Muscles of the soft palate • Laryngeal muscles (superior laryngeal n. supplies the cricothyroid; inferior laryngeal n. supplies all other laryngeal muscles)	The recurrent laryngeal n. supplies visceromotor innervation to the only muscle abducting the vocal cords, the posterior cricoarytenoid. Unilateral destruction of this nerve leads to hoarseness; bilateral destruction leads to respiratory distress (dyspnea).
	Visceral efferent (parasympathetic)	Dorsal vagal nucleus	Synapse in prevertebral or intramural ganglia. Innervate smooth muscle and glands of • Thoracic viscera (A) • Abdominal viscera (A)	
	Somatic afferent	Spinal nucleus of trigeminal nerve	Superior (jugular) ganglion receives peripheral fibers from • Dura in posterior cranial fossa (C) • Skin of ear (D), external auditory canal (E)	
	Special visceral afferent	Nucleus of solitary tract (superior part)	Inferior nodose ganglion receives peripheral processes from • Taste buds on the epiglottis and root of the tongue (F)	
	Visceral afferent	Nucleus of solitary tract (inferior part)	Inferior ganglion receives peripheral processes from • Mucosa of lower pharynx at its esophageal junction (G) • Laryngeal mucosa above (superior laryngeal n.) and below (inferior laryngeal n.) the vocal fold (G) • Pressure receptors in the aortic arch (B) • Chemoreceptors in the para-aortic body (B) • Thoracic and abdominal viscera (A)	

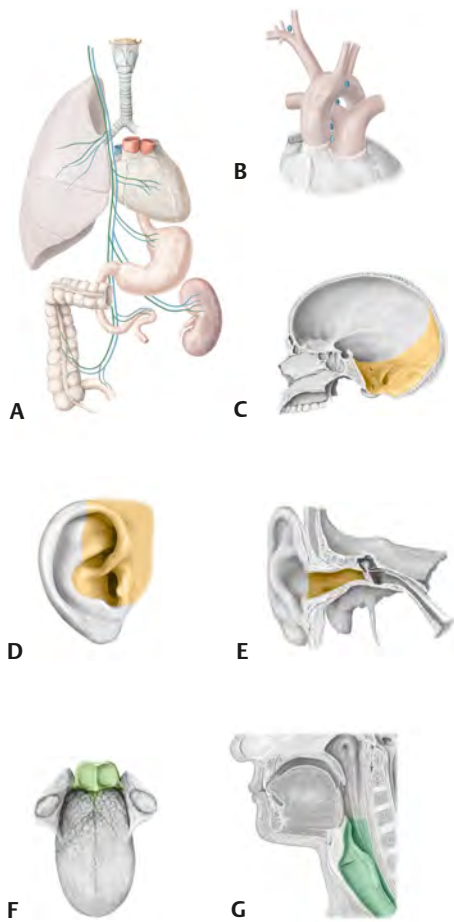
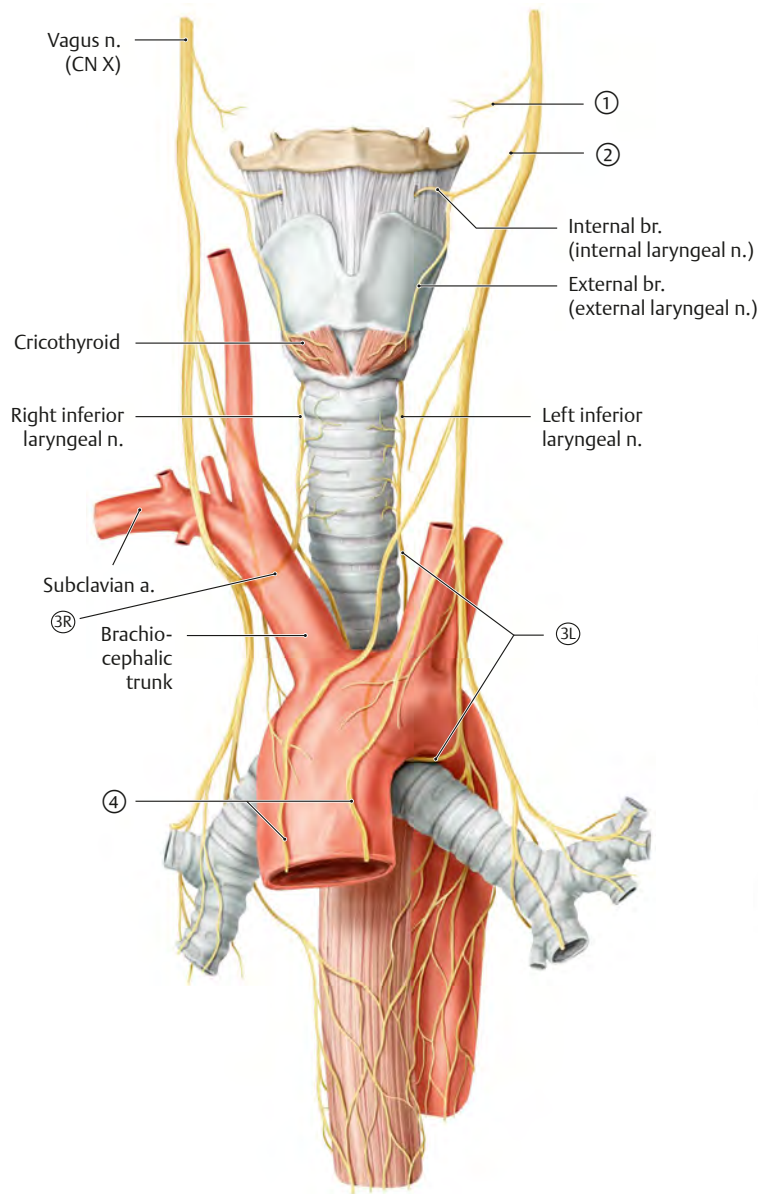


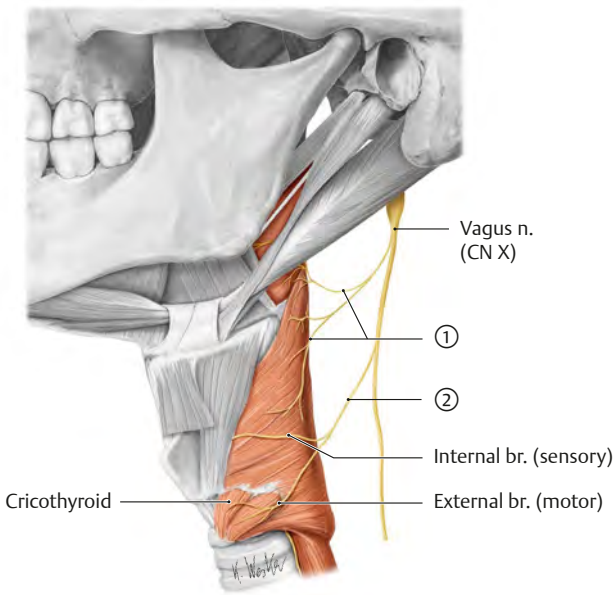
Fig. 40.22 Course of the vagus nerve

The vagus nerve gives off four major branches in the neck. The inferior laryngeal nerves are the terminal branches of the recurrent laryngeal nerves. *Note:* The left recurrent laryngeal nerve hooks around the aortic arch, while the right nerve hooks around the subclavian artery.

Table 40.10	Vagus nerve branches in the neck
①	Pharyngeal brs.
②	Superior laryngeal n.
③R	Right recurrent laryngeal n.
③L	Left recurrent laryngeal n.
④	Cervical cardiac brs.



A Branches of the vagus nerve in the neck. Anterior view.



B Innervation of the pharyngeal and laryngeal muscles. Left lateral view.

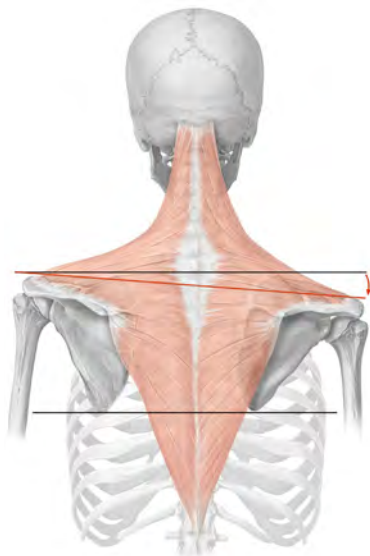
CN XI & XII: Accessory & Hypoglossal Nerves

The traditional “cranial root” of the accessory nerve (CN XI), with its cell bodies found in the nucleus ambiguus, is now considered a part of the vagus nerve (CN X) that travels with the spinal root of CN XI for a short distance before splitting off. The cranial fibers are therefore part of CN

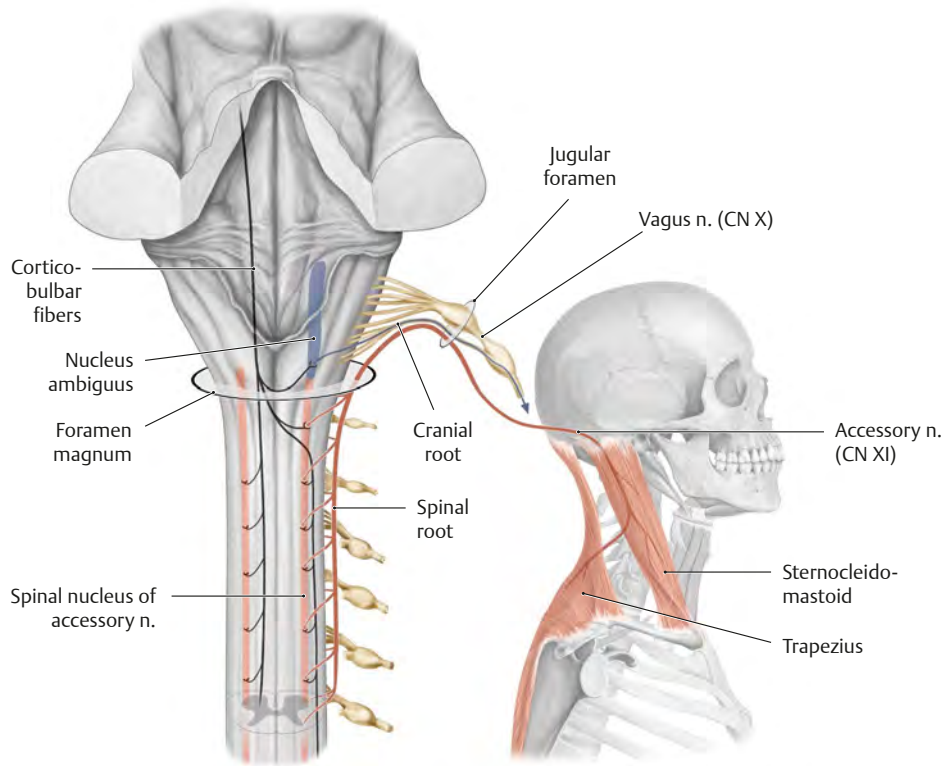
X distributed via the vagus nerve after traveling briefly with the spinal root of CN XI. The spinal root fibers, arising from the spinal nucleus of the accessory nerve are now considered to be the accessory nerve, continue on as the accessory nerve (CN XI).

Fig. 40.23 Accessory nerve
Posterior view of the brainstem with the cerebellum removed. *Note:* For didactic reasons, the muscles are displayed from the right side.

Fig. 40.24 Accessory nerve lesions
Lesion of the right accessory nerve.



A Trapezius paralysis, posterior view. See **Table 40.11** (below) for clinical correlation explanation.



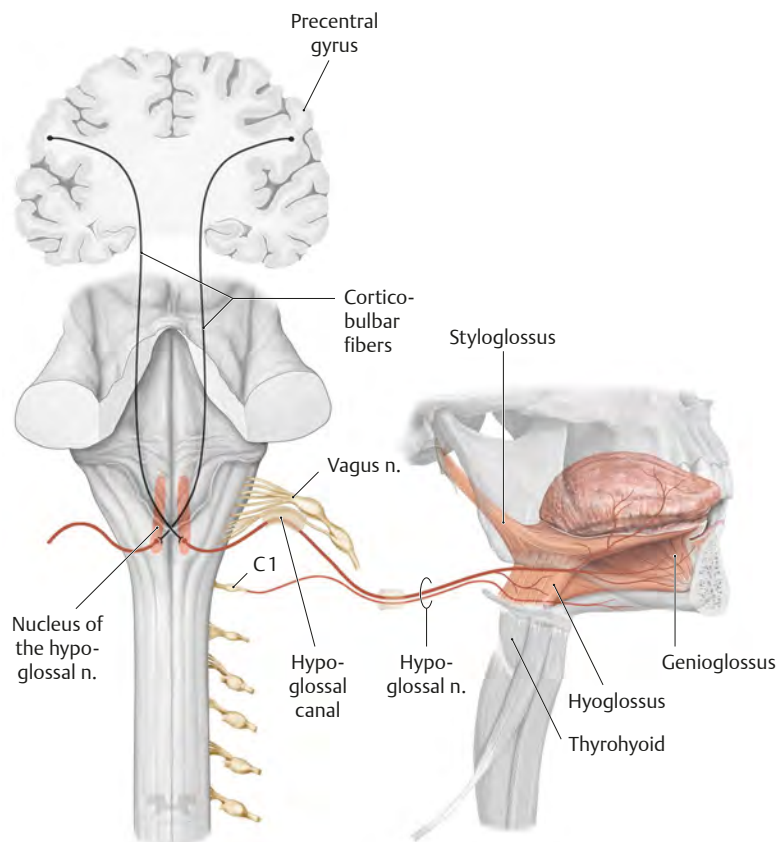
B Sternocleidomastoid paralysis, right anterolateral view. See **Table 40.11** (below) for clinical correlation explanation.



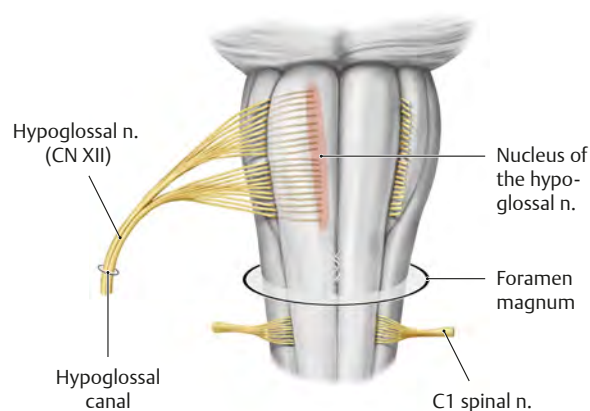
Table 40.11 Accessory nerve (CN XI)*				
Course	Fibers	Nuclei	Function	Effects of nerve injury
The spinal root emerges from the spinal cord (at the level of C1–C5/6), passes superiorly, and enters the skull through the foramen magnum, where it joins with the cranial root arising from the medulla oblongata. Both roots leave the skull through the jugular foramen. Within the jugular foramen, fibers from the cranial root pass to the vagus n. (internal branch). The spinal portion descends to the nuchal region as the external branch.	Special visceral efferent	Nucleus ambiguus (caudal part)	Join CN X and are distributed with the recurrent laryngeal n. Innervate: • All laryngeal muscles (except cricothyroid)	<i>Trapezius paralysis:</i> drooping of shoulder on affected side and difficulty raising arm above horizontal plane. This paralysis is a concern during neck operations (e.g., lymph node biopsies). An injury of the accessory n. will not result in complete trapezius paralysis (the muscle is also innervated by segments C3 and C4). <i>Sternocleidomastoid paralysis:</i> torticollis (wry neck, i.e., difficulty turning head). Unilateral lesions cause flaccid paralysis (the muscle is supplied exclusively by the accessory n.). Bilateral lesions make it difficult to hold the head upright.
	Somatic efferent	Spinal nucleus of accessory n.	Form the external branch of the accessory n. Innervate: • Trapezius • Sternocleidomastoid	
*See text at top of page, and Table 40.2 , regarding new data on cranial fibers of CN XI.				

Fig. 40.25 Hypoglossal nerve

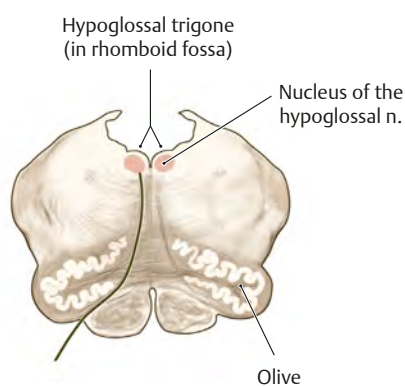
Posterior view of the brainstem with the cerebellum removed.
 Note: C1, which innervates the thyrohyoid and geniohyoid, runs briefly with the hypoglossal nerve.

**Fig. 40.26 Hypoglossal nerve nuclei**

Note: The nucleus of the hypoglossal nerve is innervated by cortical neurons from the contralateral side.



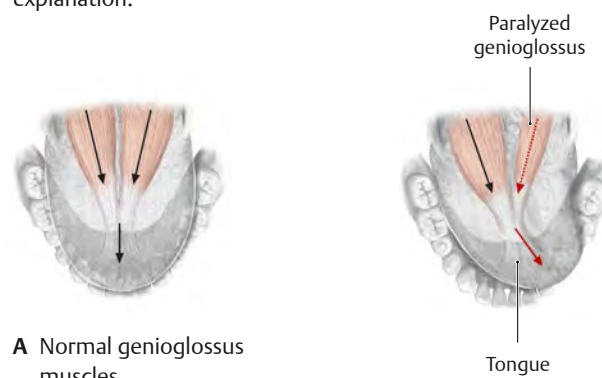
A Anterior view.



B Cross section through the medulla oblongata.

Fig. 40.27 Hypoglossal nerve lesions

Superior view. See Table 40.12 below for clinical correlation explanation.



A Normal genioglossus muscles.

B Unilateral nuclear or peripheral lesion.

Table 40.12

Hypoglossal nerve (CN XII)

Course	Fibers	Nuclei	Function	Effects of nerve injury
Emerges from the medulla oblongata, leaves the cranial cavity through the hypoglossal canal, and descends laterally to the vagus nerve. CN XII enters the root of the tongue above the hyoid bone.	Somatic efferent	Nucleus of the hypoglossal n.	Innervates: • Intrinsic and extrinsic muscles of the tongue (except the palatoglossus, supplied by CN X)	Central hypoglossal paralysis (supranuclear): tongue deviates <i>away</i> from the side of the lesion. Nuclear or peripheral paralysis: tongue deviates <i>toward</i> the affected side (due to preponderance of muscle on healthy side) Flaccid paralysis: both nuclei injured; tongue cannot be protruded.

Autonomic Innervation

Fig. 40.28 Parasympathetic nervous system (cranial part): Overview

There are four parasympathetic nuclei in the brainstem. The visceral efferent fibers of these nuclei travel along particular cranial nn., listed below.

- Visceral oculomotor (Edinger–Westphal) nucleus: oculomotor n. (CN III)
- Superior salivatory nucleus: facial n. (CN VII)
- Inferior salivatory nucleus: glossopharyngeal n. (CN IX)
- Dorsal vagal nucleus: vagus n. (CN X)

The preganglionic parasympathetic fibers often travel with multiple cranial nn. to reach their target organs. The vagus n. supplies all of the thoracic and abdominal organs as far as a point near the left colic flexure.

Note: The sympathetic fibers to the head travel along the arteries to their target organs.

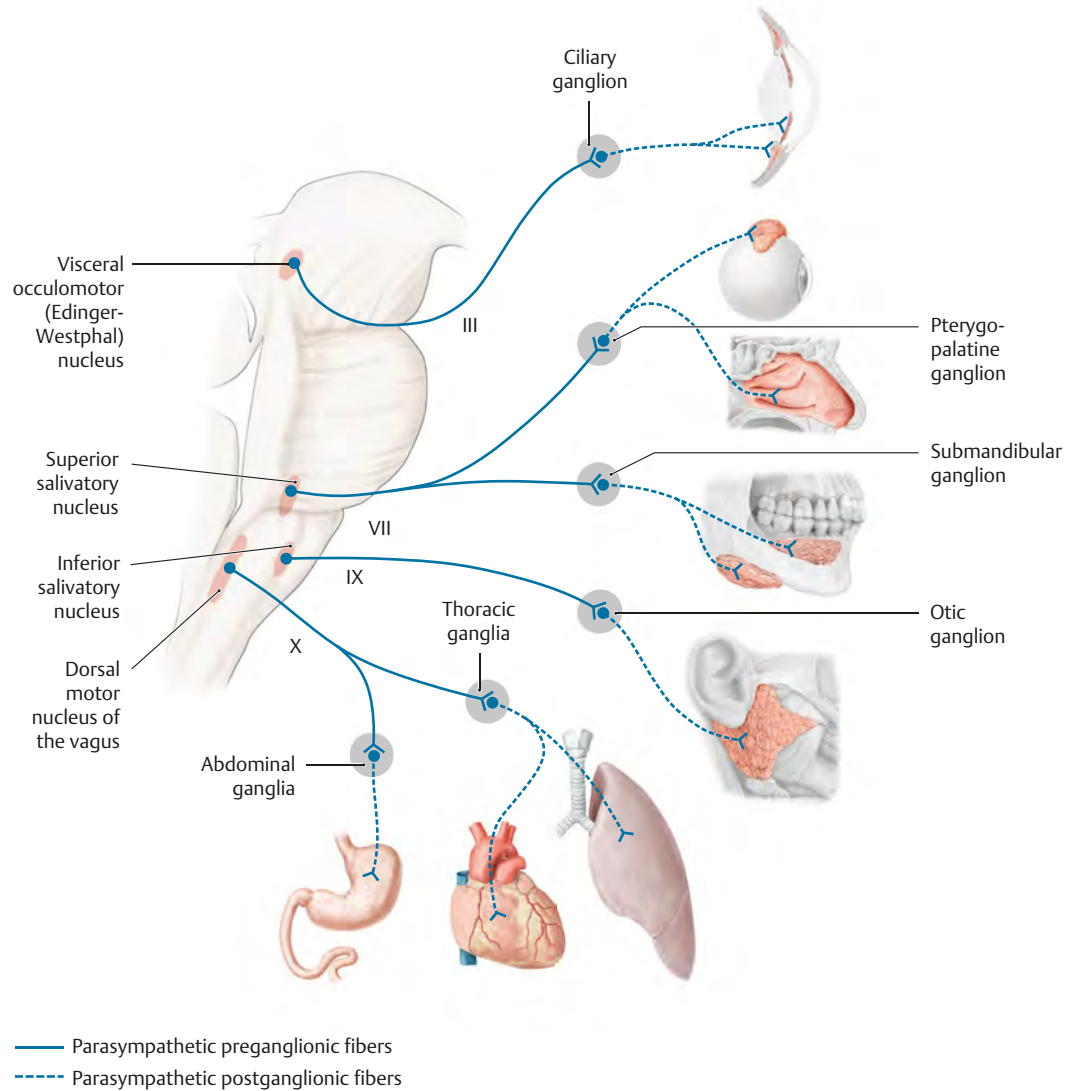


Table 40.13 Parasympathetic ganglia in the head				
Nucleus	Path of presynaptic fibers	Ganglion	Postsynaptic fibers	Target organs
Edinger–Westphal nucleus	Oculomotor n. (CN III)	Ciliary ganglion	Short ciliary nn. (CN V ₁)	Ciliary muscle (accommodation) Pupillary sphincter (miosis)
Superior salivatory nucleus	Nervus intermedius (CN VII root) → greater petrosal n. → n. of pterygoid canal	Pterygopalatine ganglion	• Maxillary n. (CN V ₂) → zygomatic n. → anastomosis → lacrimal n. (CN V ₁) • Orbital branches • Posterior superior nasal brs. • Nasopalatine nn. • Greater and lesser palatine nn.	• Lacrimal gland • Glands of nasal cavity and paranasal sinuses • Glands of gingiva • Glands of hard and soft palate • Glands of pharynx
	Nervus intermedius (CN VII root) → chorda tympani → lingual n. (CN V ₃)	Submandibular ganglion	Glandular branches	Submandibular gland Sublingual gland
Inferior salivatory nucleus	Glossopharyngeal n. (CN IX) → tympanic n. → lesser petrosal n.	Otic ganglion	Auriculotemporal n. (CN V ₃)	Parotid gland
Dorsal motor (vagal) nucleus	Vagus n. (X)	Ganglia near organs	Fine fibers in organs, not individually named	Thoracic and abdominal viscera
→ = is continuous with				

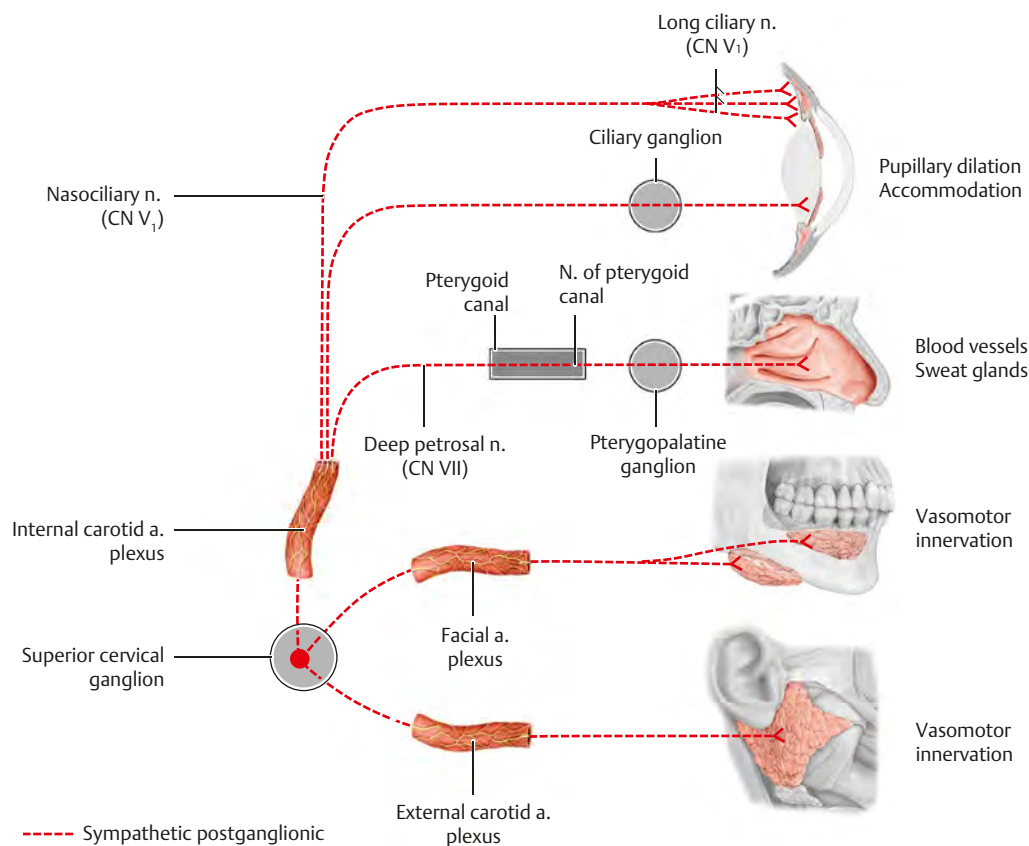


Fig. 40.29 Sympathetic innervation of the head

Sympathetic preganglionic neurons of the head originate in the lateral horn of the spinal cord (T1–T3). They exit into the sympathetic trunk and ascend to synapse in the superior cervical ganglion. Postganglionic neurons then travel with arterial plexuses. Postganglionic fibers that travel with the carotid plexus (on the internal carotid artery) join with the nasociliary nerves (of CN V₁) and then the long ciliary nerves to reach the dilator pupillae muscle (pupillary dilation); other postganglionic fibers travel through the ciliary ganglion (without synapsing) to reach the ciliary muscle to participate in accommodation. Still other postganglionic fibers from the carotid plexus leave with the deep petrosal nerve, which

joins with the greater petrosal nerve (CN VII), to form the nerve of the pterygoid canal (vidian nerve). This nerve travels to the pterygopalatine ganglion where it distributes fibers via branches of the maxillary nerve to the glands of the nasal cavity, maxillary sinus, hard and soft palate, gingiva, and pharynx, and to sweat glands and blood vessels in the head. Postganglionic fibers from the superior cervical ganglion that travel with the facial artery plexus pass through the submandibular ganglion (without synapsing) to the submandibular and sublingual glands. Other postganglionic fibers travel with the middle meningeal plexus, through the otic ganglion (without synapsing), to the parotid gland.

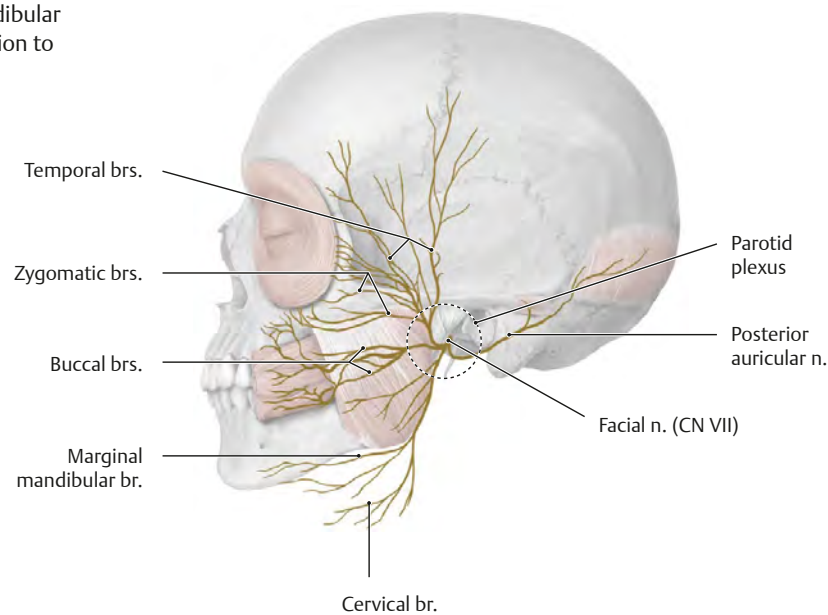
Table 40.14 Sympathetic fibers in the head

Nucleus	Path of presynaptic fibers	Ganglion	Postsynaptic fibers	Target organs
Lateral horn of spinal cord (T1–L2)	Enter sympathetic trunk and ascend to superior cervical ganglion	Superior cervical ganglion	ICA plexus → nasociliary n. (CN V ₁) → long ciliary nn. (CN V ₁)	Dilator pupillae muscle (mydriasis)
			Postganglionic fibers → ciliary ganglion* → short ciliary nn. (limited number of fibers)	Ciliary muscle (sparse sympathetic fibers contributing to accommodation)
			ICA plexus → deep petrosal n. → n. of pterygoid canal → pterygopalatine ganglion* → branches of maxillary n. (CN V ₂)	Glands of nasal cavity Sweat glands Blood vessels
			Facial a. plexus → submandibular ganglion*	Submandibular gland Sublingual gland
			External carotid a. plexus	Parotid gland
*passes through without synapsing; → = is continuous with ICA, internal carotid a.				

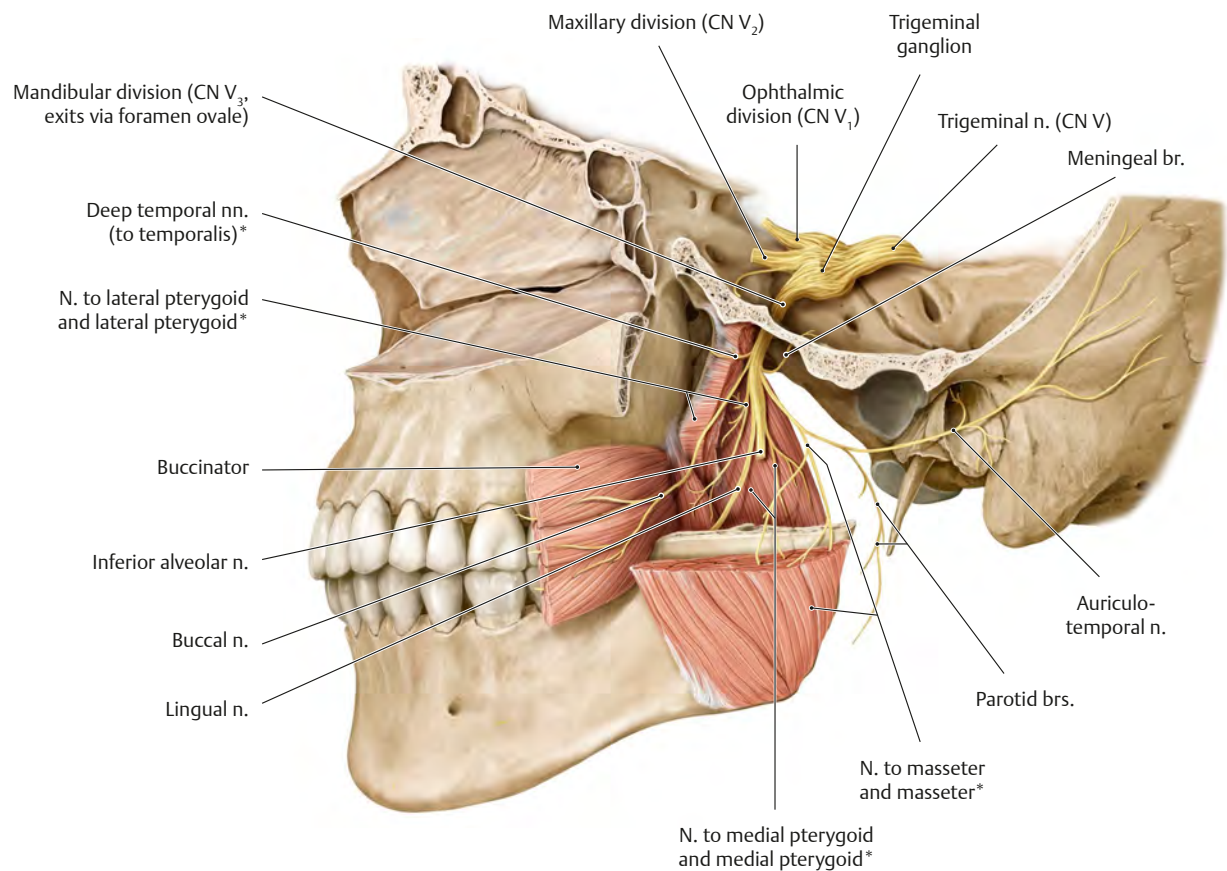
41 Neurovasculature of the Skull & Face

Innervation of the Face

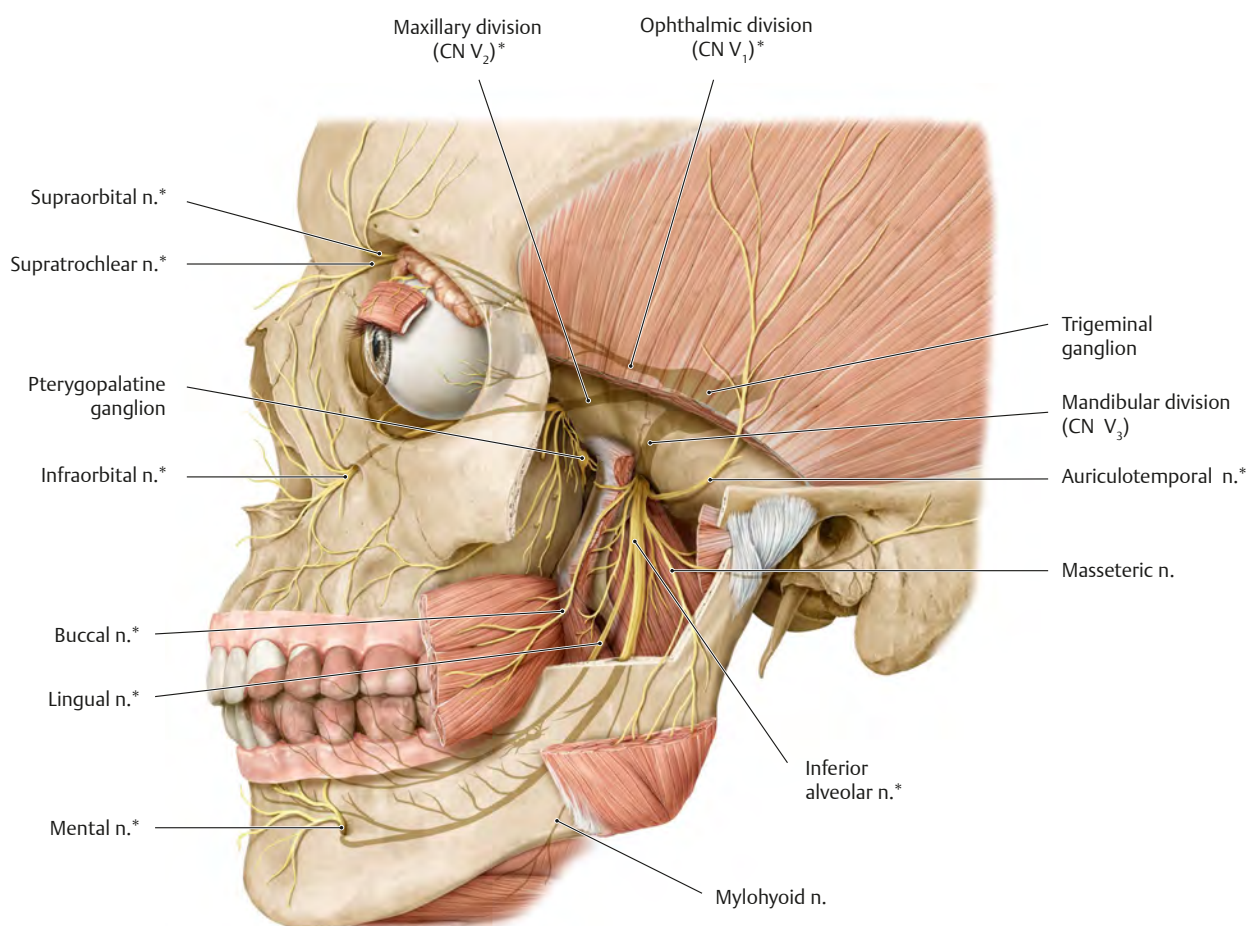
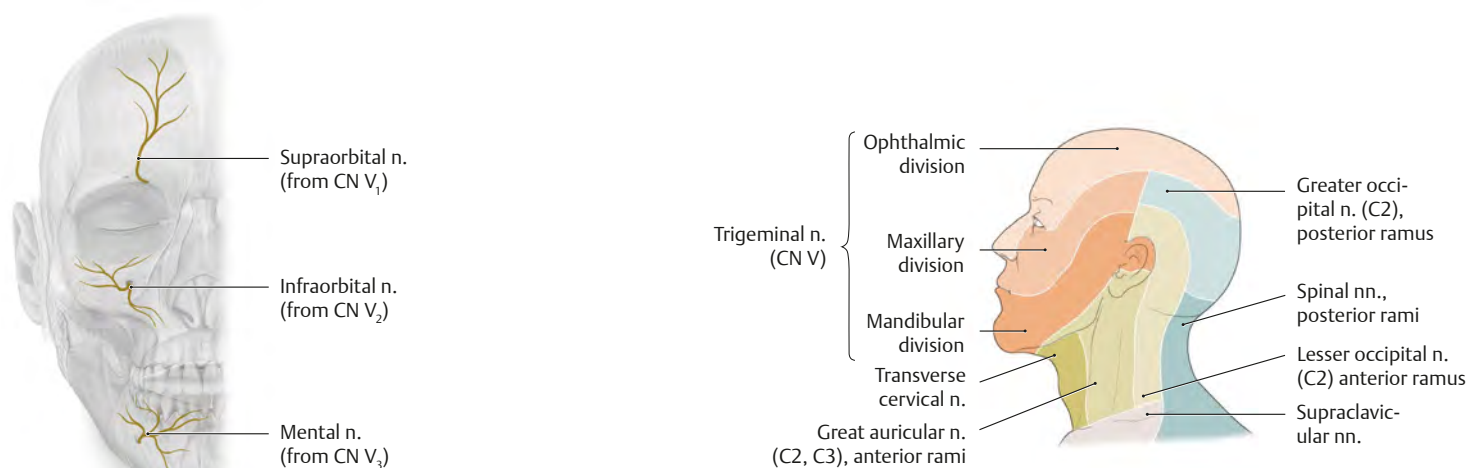
Fig. 41.1 Motor innervation of the face
 Left lateral view. Five branches of the facial nerve (CN VII) provide motor innervation to the muscles of facial expression. The mandibular division of the trigeminal nerve (CN V₃) supplies motor innervation to the muscles of mastication.



A Motor innervation of the muscles of facial expression.



B Motor innervation of the muscles of mastication (*).

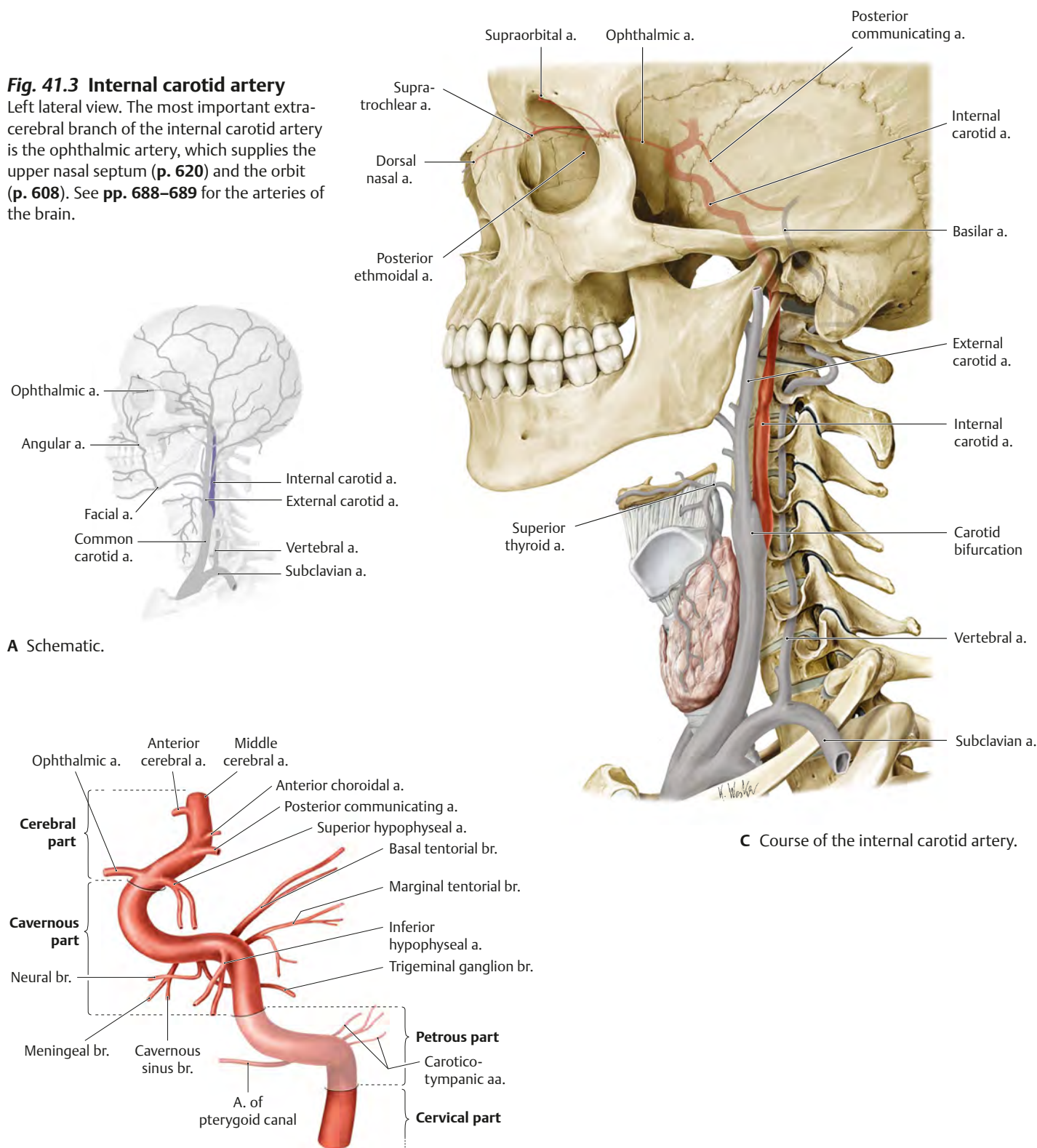
Fig. 41.2 Sensory innervation of the face

Arteries of the Head & Neck

The head and neck are supplied by branches of the common carotid artery. The common carotid splits at the carotid bifurcation into two branches: the internal and external carotid arteries. The internal carotid

chiefly supplies the brain (p. 688), although its branches anastomose with the external carotid in the orbit and nasal septum. The external carotid is the major supplier of structures of the head and neck.

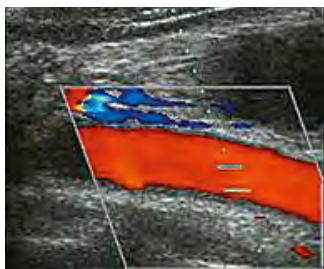
Fig. 41.3 Internal carotid artery
Left lateral view. The most important extra-cerebral branch of the internal carotid artery is the ophthalmic artery, which supplies the upper nasal septum (p. 620) and the orbit (p. 608). See pp. 688–689 for the arteries of the brain.



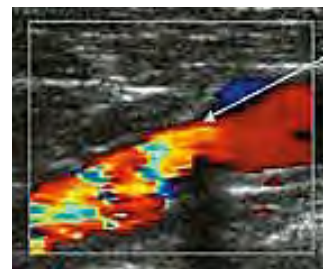
Carotid artery atherosclerosis

The carotid artery is often affected by atherosclerosis, a hardening of arterial walls due to plaque formation. The examiner can determine the status of the arteries using ultrasound. *Note:* The absence of atherosclerosis in the carotid

artery does not preclude coronary heart disease or atherosclerotic changes in other locations.



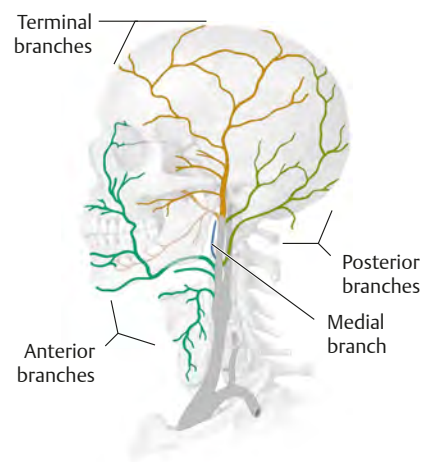
A Common carotid artery with "normal" flow.



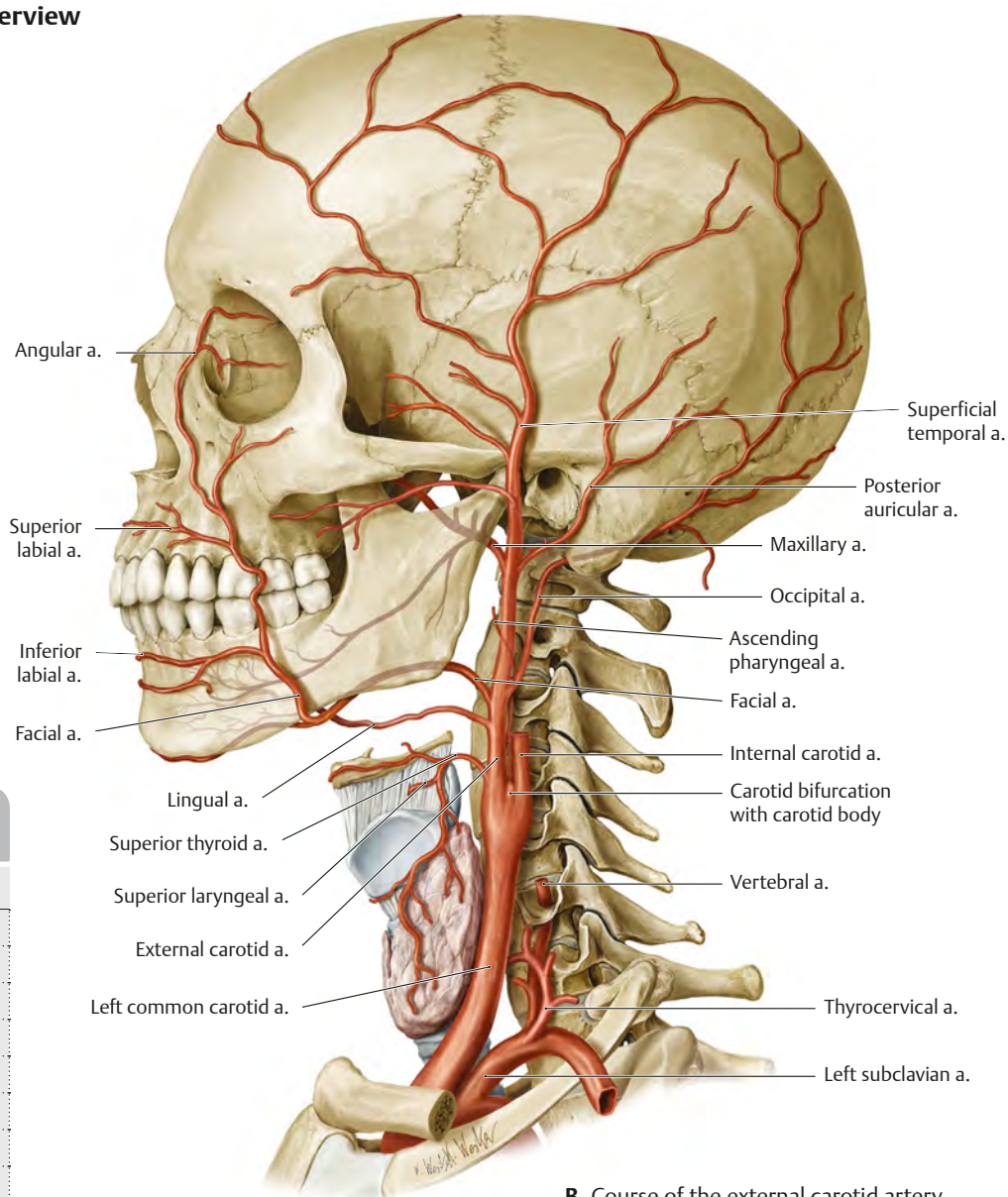
B Calcified plaque in the carotid bulb.

Fig. 41.4 External carotid artery: Overview

Left lateral view.



A Schematic of the external carotid artery.



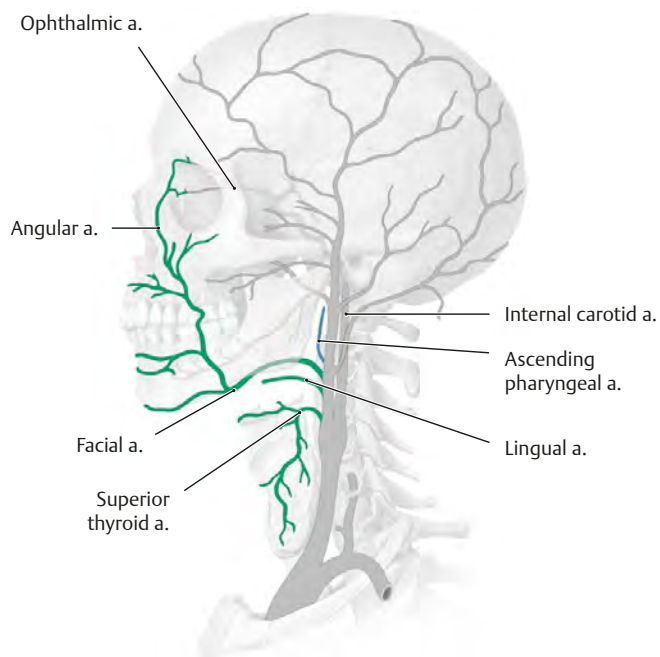
B Course of the external carotid artery.

Table 41.1

Branches of the external carotid artery

Group	Artery
Anterior (p. 584)	Superior thyroid a.
	Lingual a.
	Facial a.
Medial (p. 584)	Ascending pharyngeal a.
Posterior (p. 585)	Occipital a.
	Posterior auricular a.
Terminal (p. 585)	Maxillary a.
	Superficial temporal a.

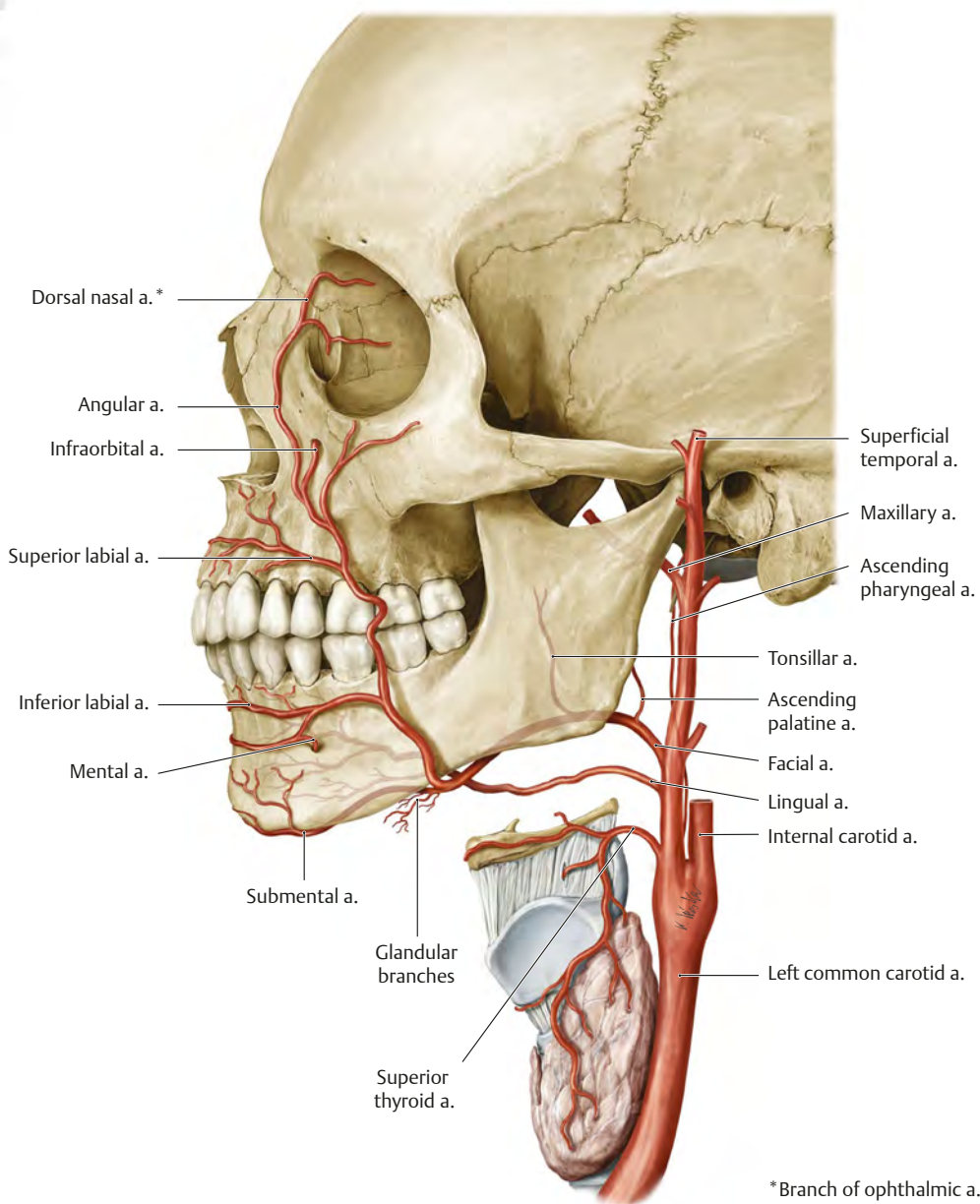
External Carotid Artery: Anterior, Medial & Posterior Branches



A Arteries of the anterior and medial branches. The copious blood supply to the face makes facial injuries bleed profusely but heal quickly. There are extensive anastomoses between branches of the external carotid artery and between the external carotid artery and branches of the ophthalmic artery.

Fig. 41.5 Anterior and medial branches

Left lateral view. The arteries of the anterior aspect supply the anterior structures of the head and neck, including the orbit (p. 606), ear (p. 632), larynx (p. 530), pharynx (p. 654), and oral cavity. *Note:* The angular artery anastomoses with the dorsal nasal artery of the internal carotid (via the ophthalmic artery).



B Course of the anterior and medial branches.

*Branch of ophthalmic a.

Fig. 41.6 Posterior branches

Left lateral view. The posterior branches of the external carotid artery supply the ear (p. 632), posterior skull (p. 594), and posterior neck muscles (p. 541).

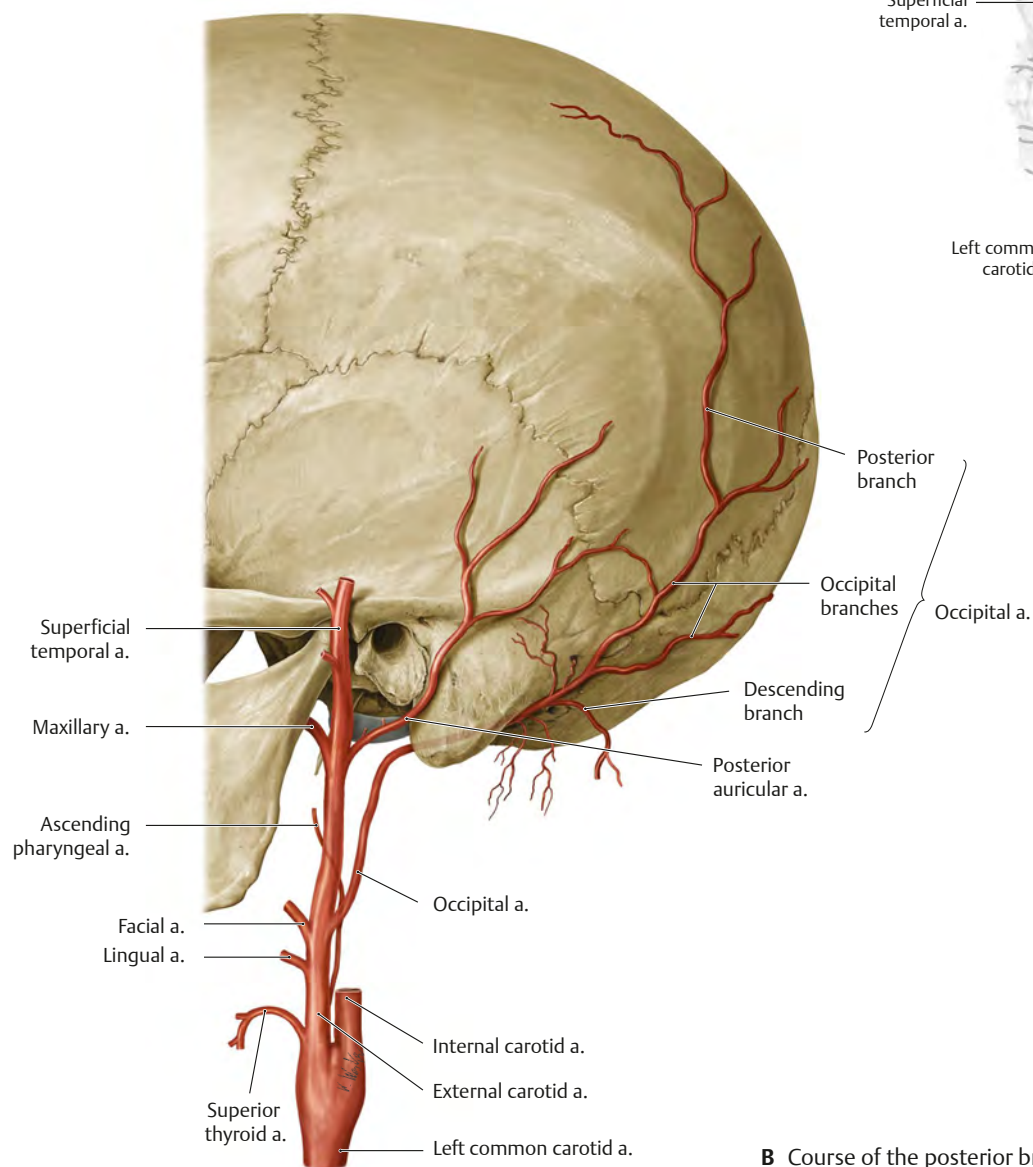


Table 41.2

Anterior, medial, and posterior branches of the external carotid artery

Branch	Artery	Divisions and distribution
Anterior brs.	Superior thyroid a.	Glandular br. (to thyroid gland); superior laryngeal a.; sternocleidomastoid br.
	Lingual a.	Dorsal lingual brs. (to base of tongue, palatoglossal arch, tonsil, soft palate and epiglottis); sublingual a. (to sublingual gland, tongue, oral floor, oral cavity); sublingual br. to the sublingual gland; deep lingual a.
	Facial a.	Ascending palatine a. (to pharyngeal wall, soft palate, pharyngotympanic tube); tonsillar branch (to palatine tonsils); submental a. (to oral floor, submandibular gland); labial aa.; angular a. (to nasal root)
Medial br.	Ascending pharyngeal a.	Pharyngeal brs.; inferior tympanic a. (to mucosa of inner ear); posterior meningeal a.
Posterior brs.	Occipital a.	Occipital brs.; descending br. (to posterior neck muscles)
	Posterior auricular a.	Stylomastoid a. (to facial n. in facial canal); posterior tympanic a.; auricular br.; occipital br.; parotid br.

For terminal brs., see Table 41.3 (p. 586).

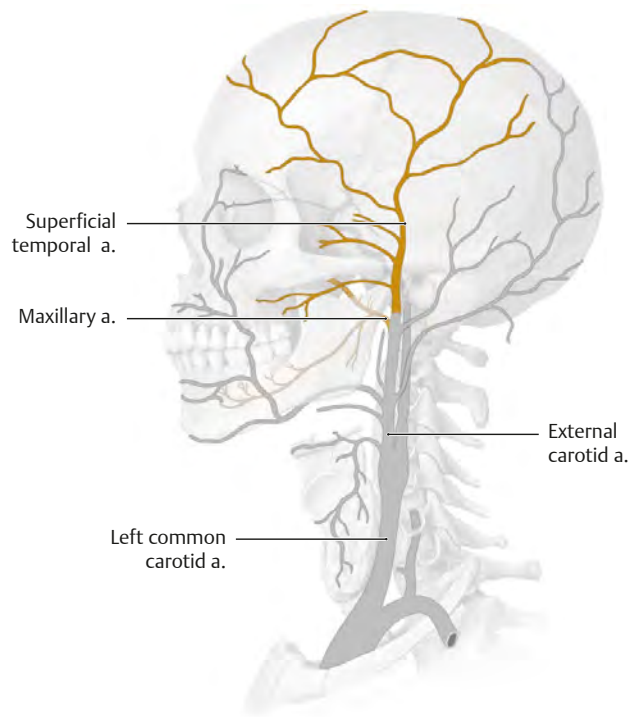
External Carotid Artery: Terminal Branches

The terminal branches of the external carotid artery consist of two major arteries: superficial temporal and maxillary. The superficial temporal

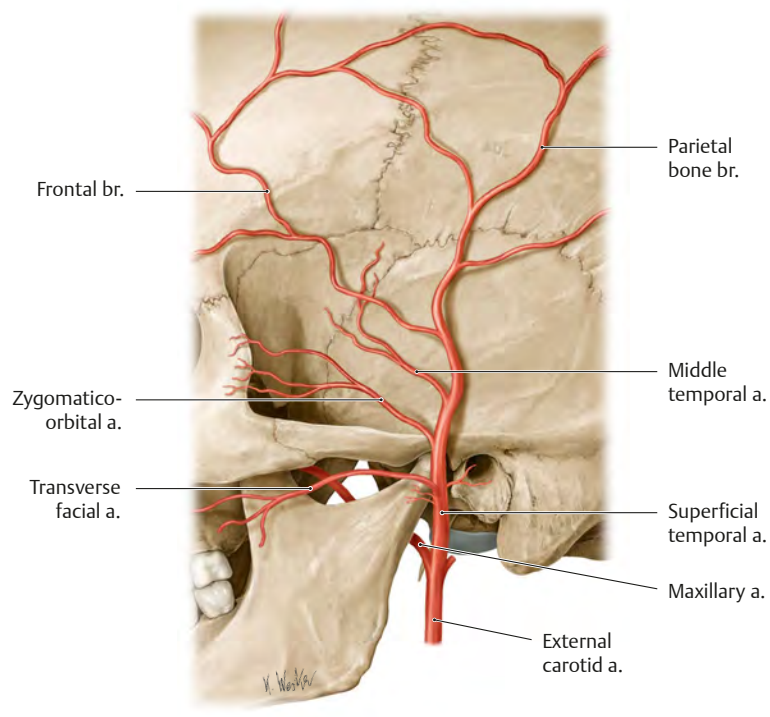
artery supplies the lateral skull. The maxillary artery is a major artery for internal structures of the face.

Fig. 41.7 Superficial temporal artery

Left lateral view. Inflammation of the superficial temporal artery due to temporal arteritis can cause severe headaches. The course of the frontal branch of the artery can often be seen superficially under the skin of elderly patients.



A Arteries of the terminal branch.

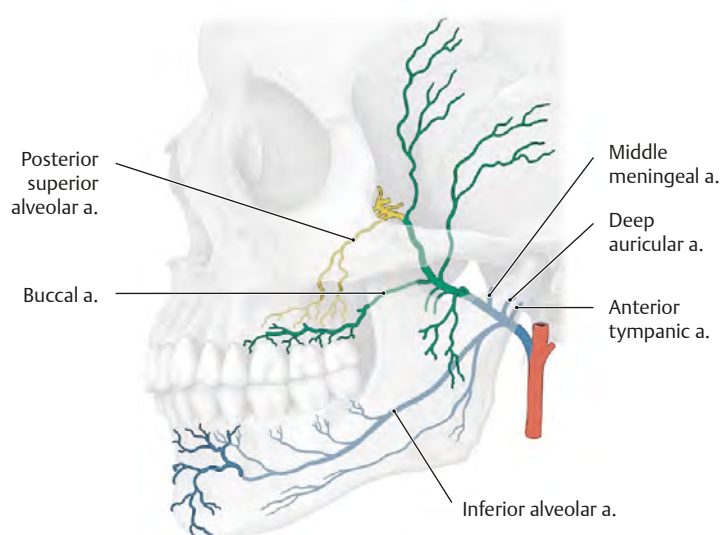


B Course of the superficial temporal artery.

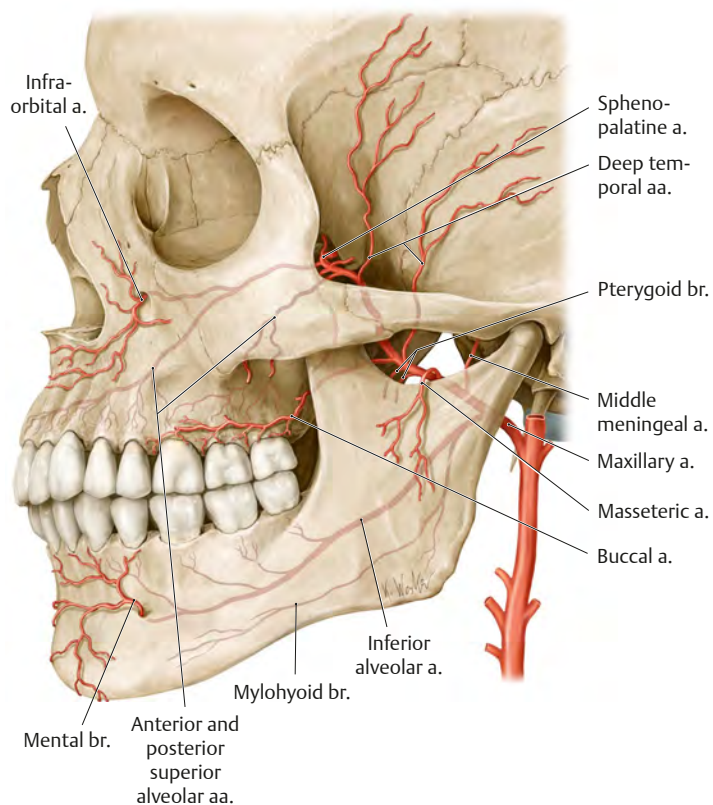
Table 41.3 Terminal branches of the external carotid artery					
Branch	Artery		Divisions and distribution		
External carotid a.	Superficial temporal a.		Transverse facial a. (to soft tissues below the zygomatic arch); frontal brs.; parietal brs.; zygomatico-orbital a. (to lateral orbital wall)		
	Maxillary a.	Mandibular part	Inferior alveolar a. (to mandible, teeth, gingiva); middle meningeal a.; deep auricular a. (to temporomandibular joint, external auditory canal); anterior tympanic a.		
		Pterygoid part	Masseteric a.; deep temporal brs.; pterygoid brs.; buccal a.		
		Pterygopalatine part	Posterosuperior alveolar a. (to maxillary molars, maxillary sinus, gingiva); infraorbital a. (to maxillary alveoli)		
			Descending palatine a.	Greater palatine a. (to hard palate)	
				Lesser palatine a. (to soft palate, palatine tonsil, pharyngeal wall)	
				Lateral posterior nasal aa. (to lateral wall of nasal cavity, conchae)	
	Sphenopalatine a.	Posterior septal brs. (to nasal septum)			
* Parts not shown here. See Fig 41.27 (p. 599) and Table 41.8 (p. 601).					

Fig. 41.8 Maxillary artery

Left lateral view. The maxillary artery consists of three parts: mandibular (blue), pterygoid (green), and pterygopalatine (yellow).



A Divisions of the maxillary artery.

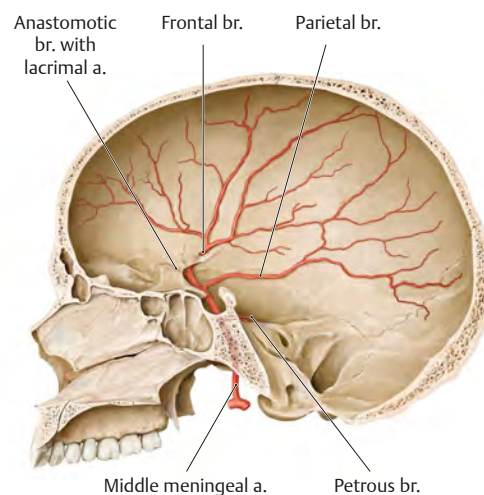


B Course of the maxillary artery.

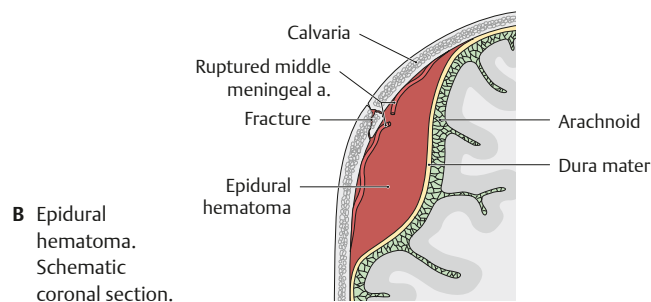
Clinical box 41.2

Middle meningeal artery

The middle meningeal artery supplies the meninges and overlying calvaria. Rupture of the artery (generally due to head trauma) results in an epidural hematoma.



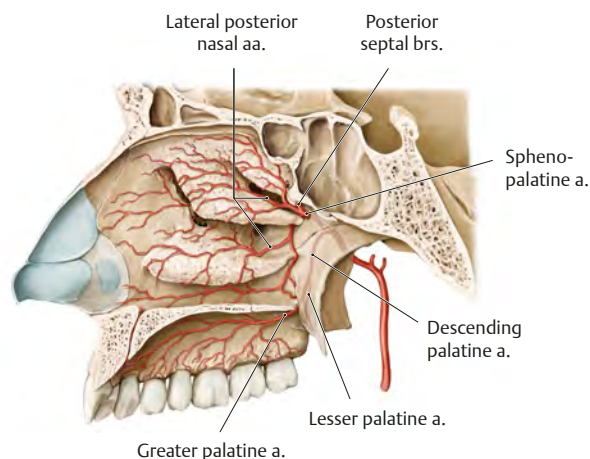
A Right middle meningeal artery, medial view of opened skull.



B Epidural hematoma. Schematic coronal section.

Sphenopalatine artery

The sphenopalatine artery supplies the wall of the nasal cavity. Excessive nasopharyngeal bleeding from the branches of the sphenopalatine artery may necessitate ligation of the maxillary artery in the pterygopalatine fossa.

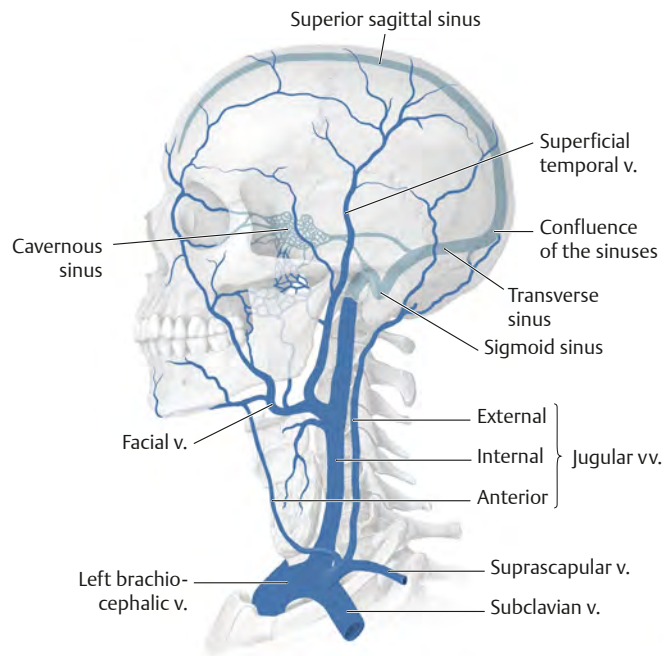


C Lateral wall of right nasal cavity, medial view.

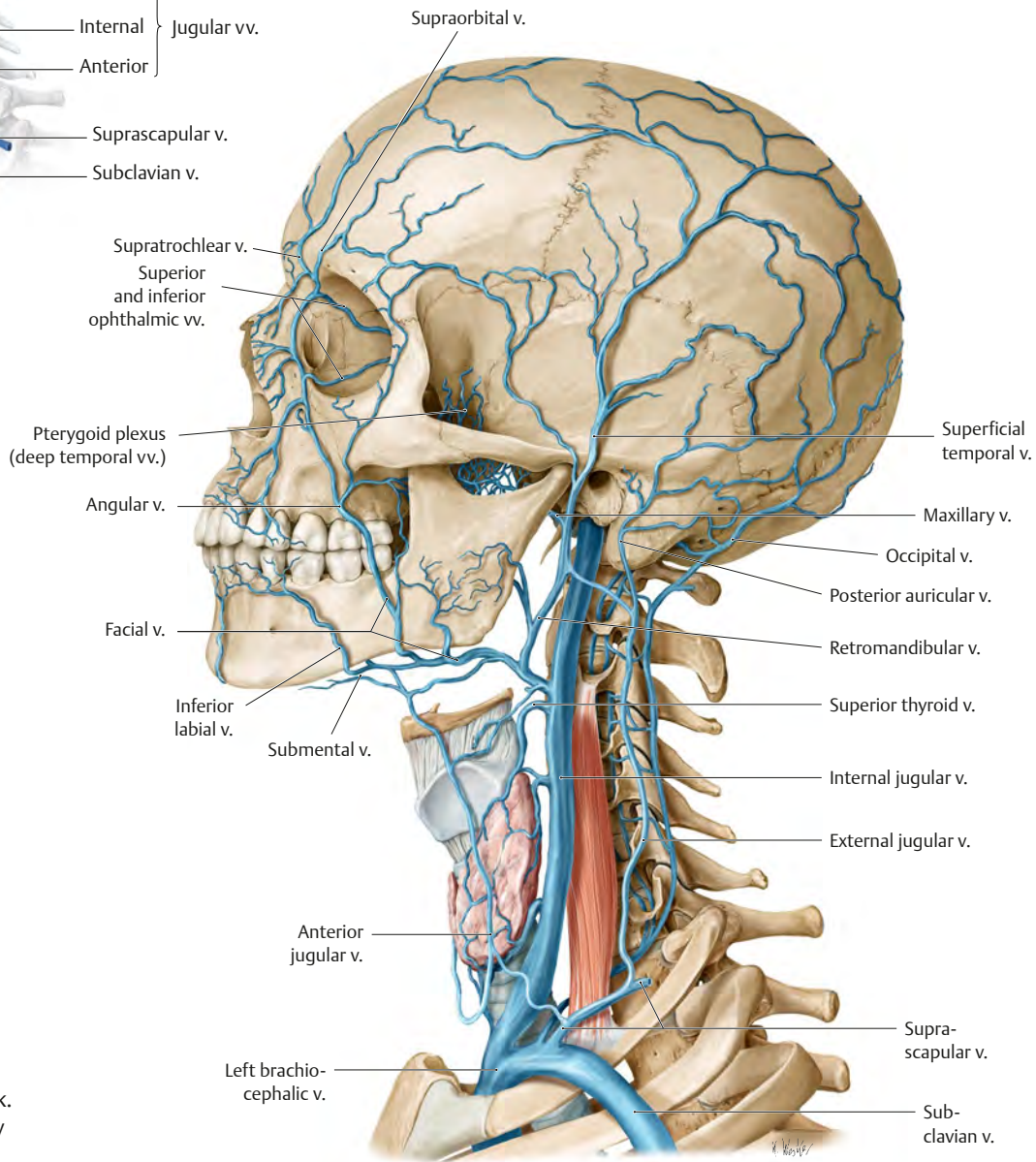
Veins of the Head & Neck

Fig. 41.9 Veins of the head and neck
 Left lateral view. The veins of the head and neck drain into the brachio-
 cephalic vein. *Note:* The left and right brachiocephalic veins are not
 symmetrical.

Table 41.4 Principal superficial veins		
Vein	Region drained	Location
Internal jugular v.	Interior of skull (including brain)	Within carotid sheath
External jugular v.	Superficial head	Within superficial cervical fascia
Anterior jugular v.	Neck, portions of head	



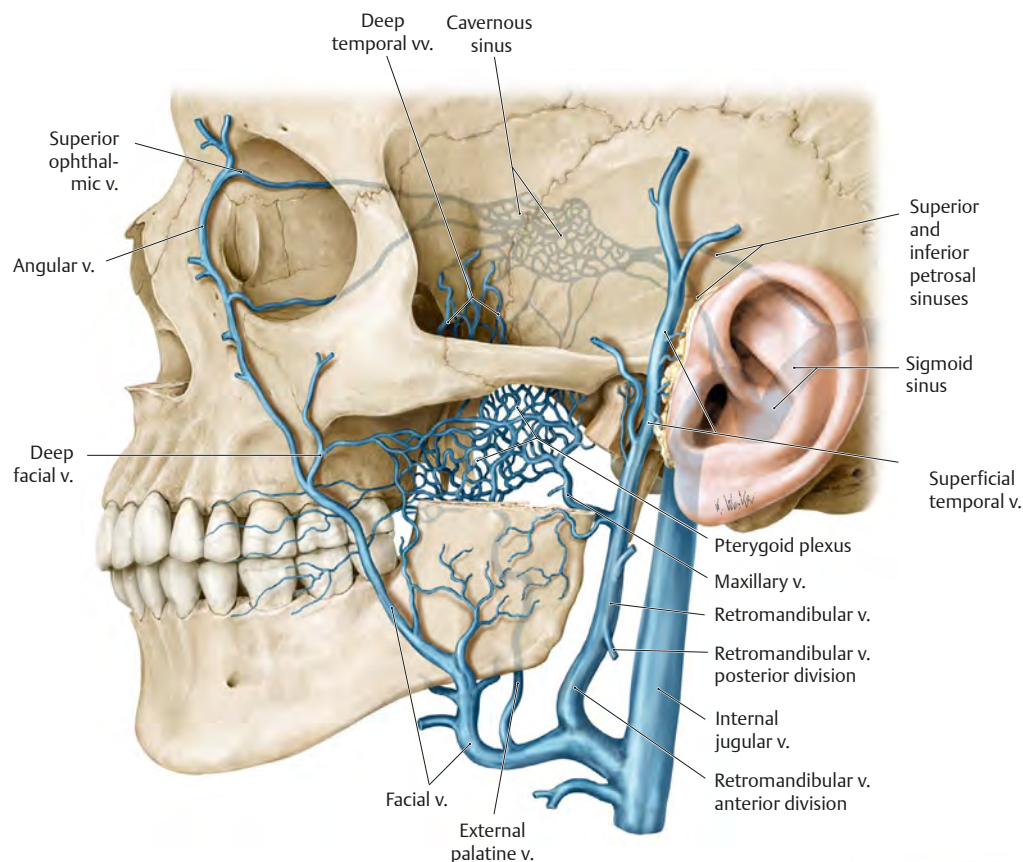
A Principal veins of the head and neck.



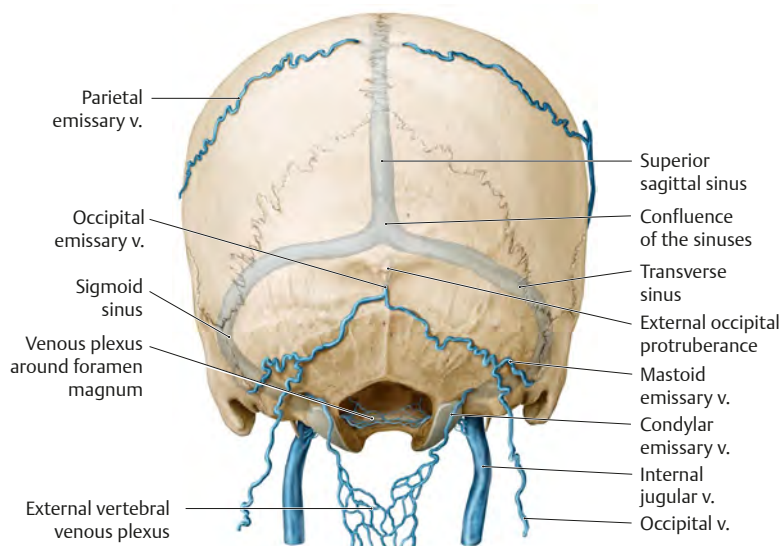
B Superficial veins of the head and neck.
Note: The course of the veins is highly
 variable.

Fig. 41.10 Deep veins of the head

Left lateral view. *Removed:* Upper ramus, condylar and coronoid processes of mandible. The pterygoid plexus is a venous network situated between the mandibular ramus and the muscles of mastication. The cavernous sinus connects branches of the facial vein to the sigmoid sinuses.

**Fig. 41.11 Veins of the occiput**

Posterior view. The superficial veins of the occiput communicate with the dural venous sinuses via emissary veins that drain to diploic veins (calvaria, **p. 545**). *Note:* The external vertebral venous plexus traverses the entire length of the spine (**p. 45**).

**Table 41.5 Venous anastomoses**

The extensive venous anastomoses in this region provide routes for the spread of infections.

Extracranial vein	Connecting vein	Venous sinus
Angular v.	Superior and inferior ophthalmic vv.	Cavernous sinus*
Vv. of palatine tonsil	Pterygoid plexus; inferior ophthalmic v.	
Superficial temporal v.	Parietal emissary vv.	Superior sagittal sinus
Occipital v.	Occipital emissary v.	Transverse sinus, confluence of the sinuses
Posterior auricular v.	Mastoid emissary v.	Sigmoid sinus
External vertebral venous plexus	Condylar emissary v.	

*Deep spread of bacterial infection from the facial region may result in cavernous sinus thrombosis.

Meninges

The brain and spinal cord are covered by membranes called meninges. The meninges are composed of three layers: dura mater (dura), arachnoid mater (arachnoid membrane), and pia mater. The subarachnoid

space, located between the arachnoid mater and pia mater, contains cerebrospinal fluid (CSF, see p. 684). See p. 40 for the coverings of the spinal cord.

Fig. 41.12 Layers of the meninges
See pp. 686–687 for the veins of the brain.

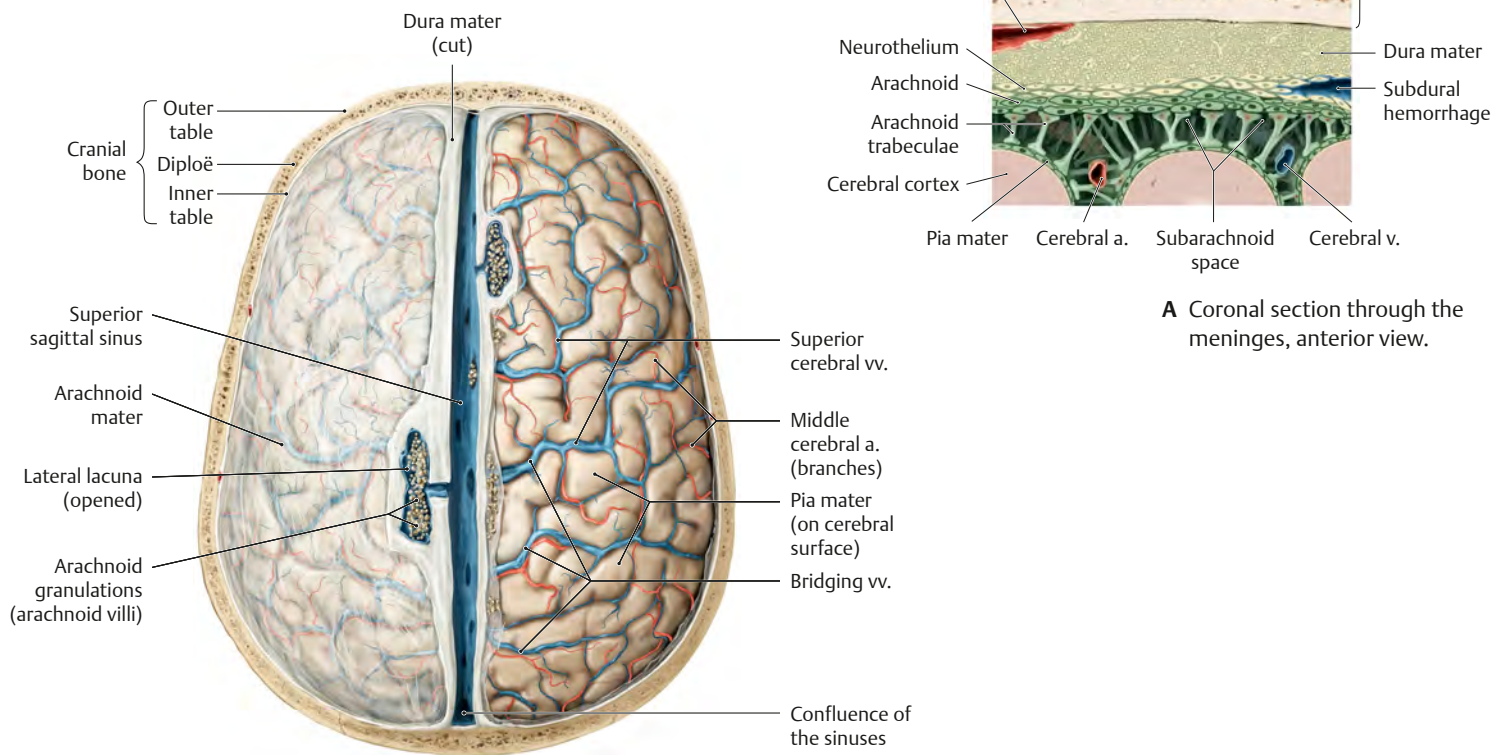
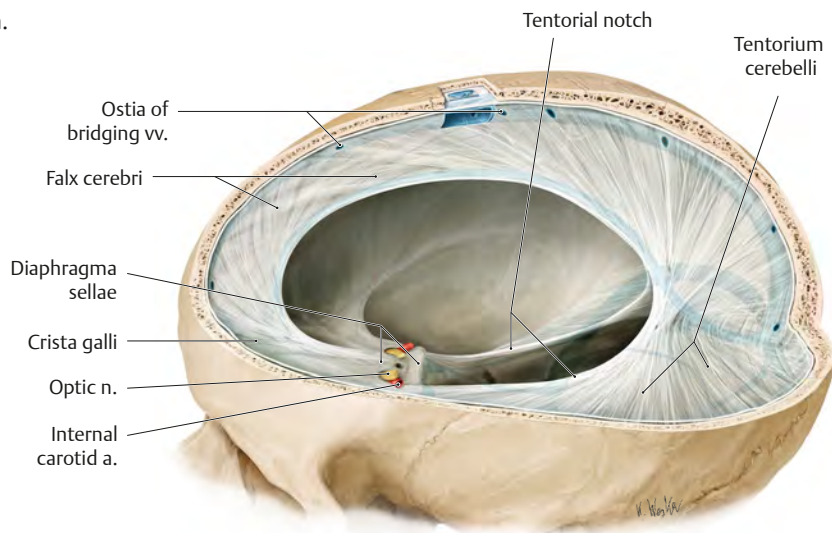


Fig. 41.13 Dural folds (septa)

Left anterior oblique view. Two layers of meningeal dura come together, after separating from the periosteal dura during formation of a dural (venous) sinus, to form a dural fold or septum. These include the falx cerebri (separating right and left cerebral hemispheres); the tentorium cerebelli (supporting the cerebrum to keep it from crushing the underlying cerebellum); the falx cerebelli (not shown, separating right and left cerebellar lobes under the tentorium); and the diaphragma sellae (forming the roof over the hypophyseal fossa and invaginated by the hypophysis).



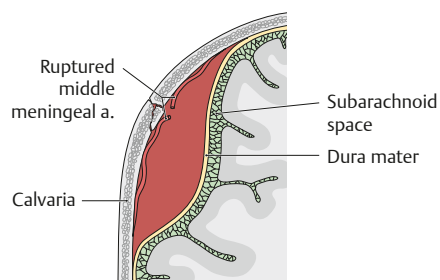


Clinical box 41.3

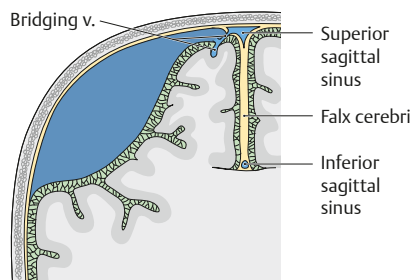
Extracerebral hemorrhages

Bleeding between the bony calvarium and the soft tissue of the brain (extracerebral hemorrhage) exerts pressure on the brain. A rise of intracranial pressure may damage brain tissue both at the bleeding site and in more

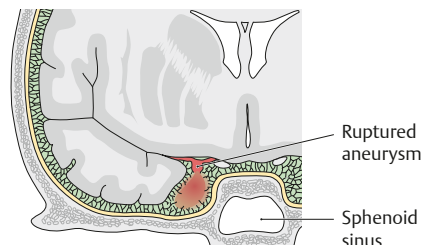
remote brain areas. Three types of intracranial hemorrhage are distinguished based on the relationship to the dura mater. See pp. 688–689 for the arteries and pp. 686–687 for the veins of the brain.



A Epidural hematoma (above the dura).



B Subdural hematoma (below the dura).



C Subarachnoid hemorrhage.

Fig. 41.14 Arteries of the dura mater

Midsagittal section, left lateral view. See pp. 688–689 for the arteries of the brain.

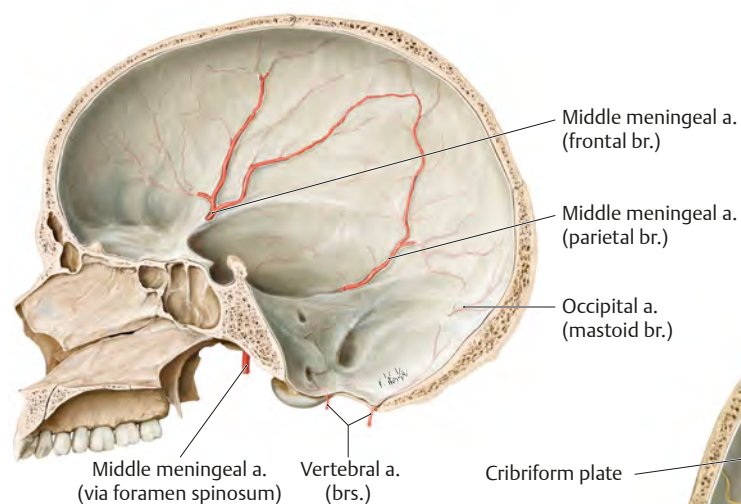
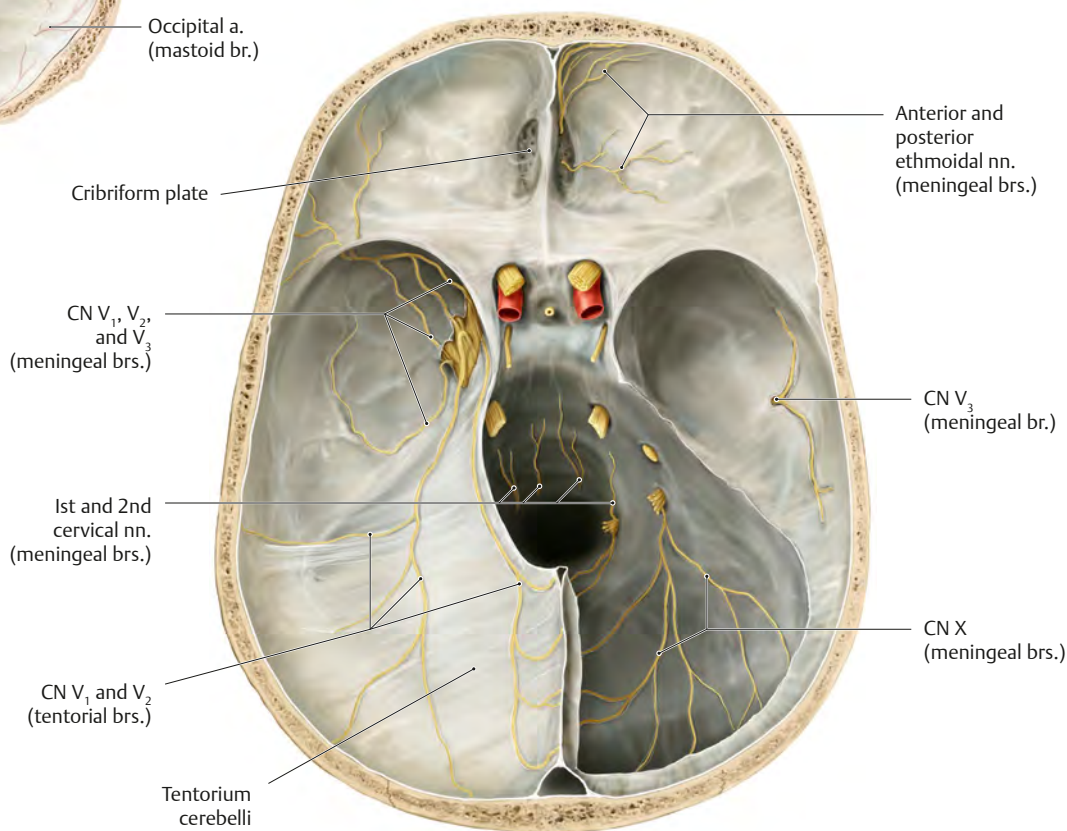


Fig. 41.15 Innervation of the dura mater

Superior view. Removed: Tentorium cerebelli (right side).

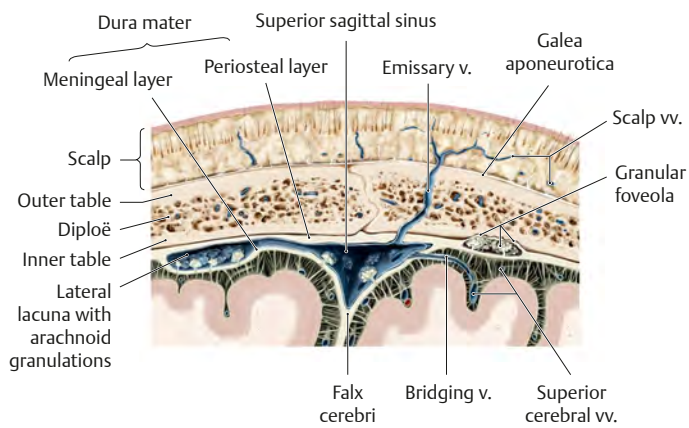


Dural Sinuses

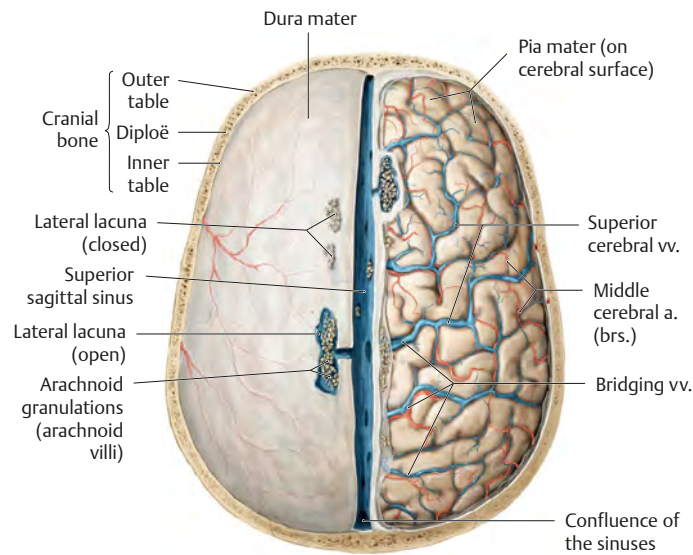
The dura mater is composed of two layers that separate in the region of a venous sinus into an outer periosteal layer, which lines the calvaria and an inner meningeal layer, which forms the unattached boundaries of the sinus. In the region of a sinus, the two meningeal dural layers

come together after forming the sinus to create a dural fold, or septa (see Fig. 41.13, p. 590). The network of venous sinuses collect blood from the scalp, the calvaria, and the brain and eventually drain into the internal jugular vein at the jugular foramen.

Fig. 41.16 Formation of a dural sinus



A Structure of a dural sinus. Superior sagittal sinus, coronal section, anterior view.



B Superior sagittal sinus in situ. Superior view of opened cranial cavity. The roof of the sinus (the periosteal layer of the dura attached to the calvaria) is removed. *Left side:* Areas of dura mater removed to show arachnoid granulations (protrusions of the arachnoid layer of the meninges) in the sinus. *Right side:* Dura mater and arachnoid layers removed to reveal pia mater adhering to the cerebral cortex.

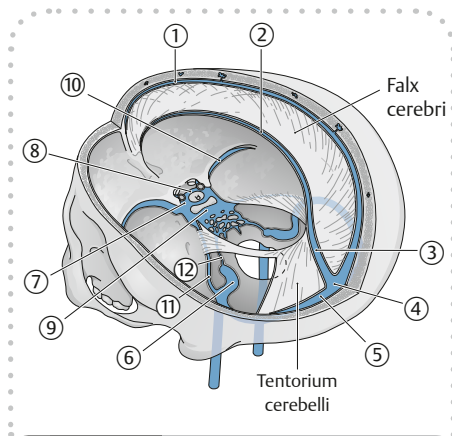


Fig. 41.17 Dural sinuses in the cranial cavity

Superior view of opened cranial cavity. Dural sinus system ghosted in blue. *Removed:* Tentorium cerebelli (right side).

Table 41.6 Principal dural sinuses			
Upper group		Lower group	
①	Superior sagittal sinus	⑦	Cavernous sinus
②	Inferior sagittal sinus	⑧	Anterior intercavernous sinus
③	Straight sinus	⑨	Posterior intercavernous sinus
④	Confluence of the sinuses	⑩	Sphenoparietal sinus
⑤	Transverse sinus	⑪	Superior petrosal sinus
⑥	Sigmoid sinus	⑫	Inferior petrosal sinus

The occipital sinus is also included in the upper group (see Fig. 49.1, p. 686).

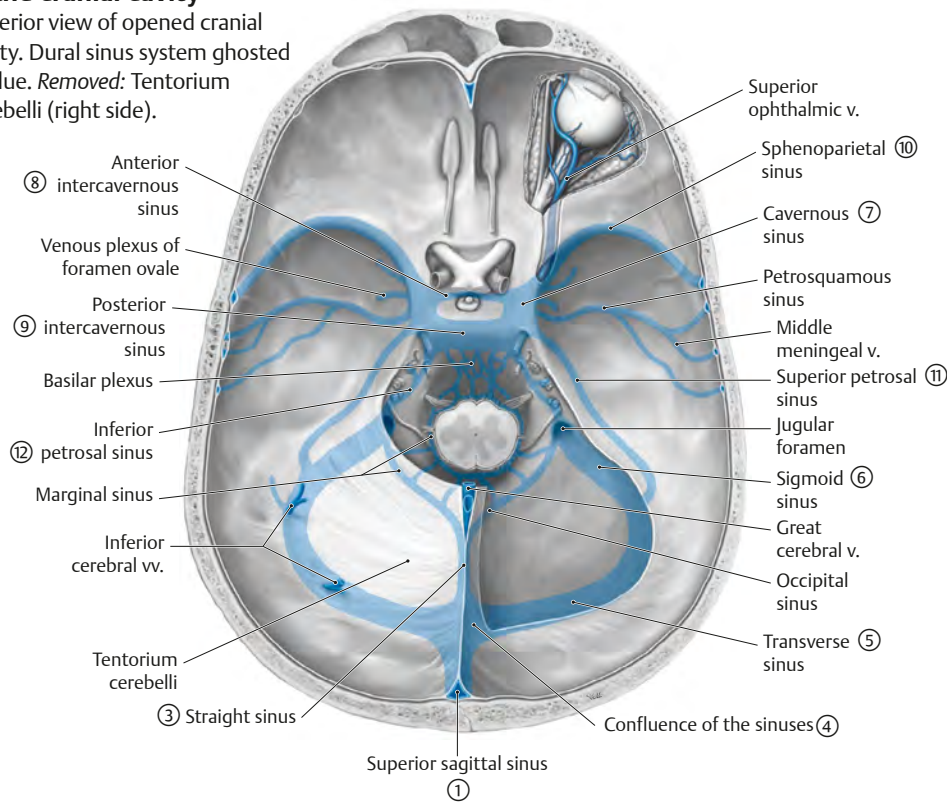
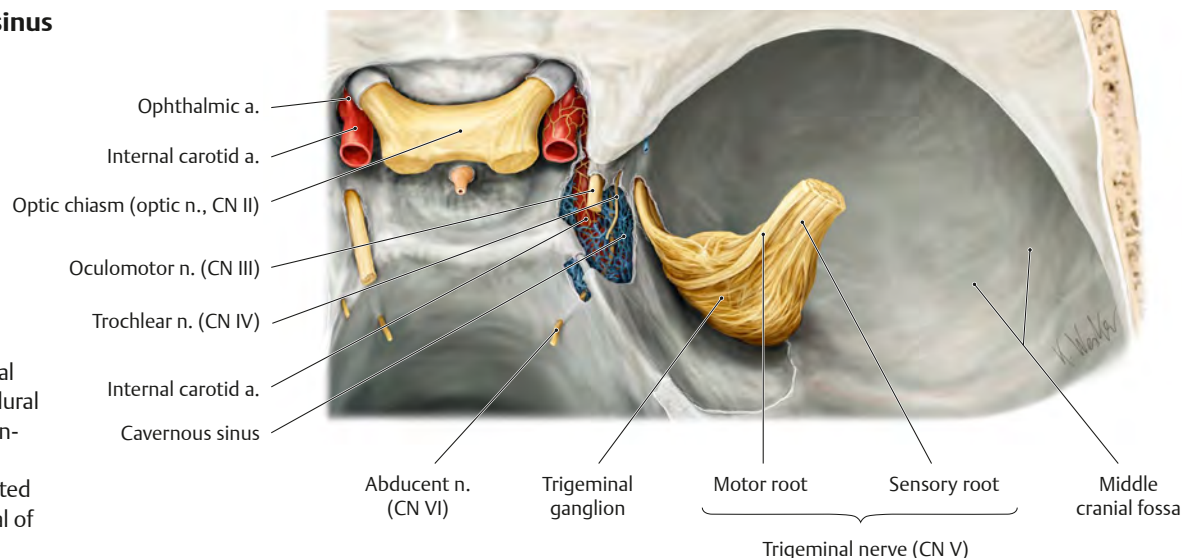


Fig. 41.18 Cavernous sinus and cranial nerves

A Superior view of the right anterior and middle cranial fossae. *Removed:* Lateral dural wall and roof of the cavernous sinus. The trigeminal ganglion is cut and retracted laterally following removal of its dural covering



B Topography of the extradural course of the abducent nerve along the clivus and in the left cavernous sinus. Left lateral view. *Note* the long extradural path the abducent nerve follows along the clivus. It runs within the subarachnoid space, pierces the dura mater, passes under Gruber's ligament through Dorello's canal and enters the cavernous sinus at the tip of the petrous temporal bone (at the junction of the middle and posterior cranial fossae). It courses through the cavernous sinus lateral to the internal carotid artery to reach the orbit through the superior orbital fissure.

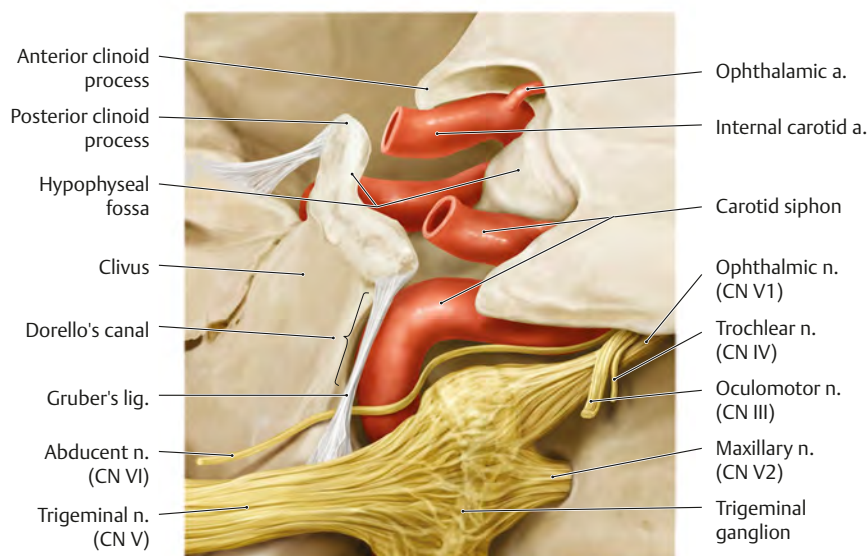
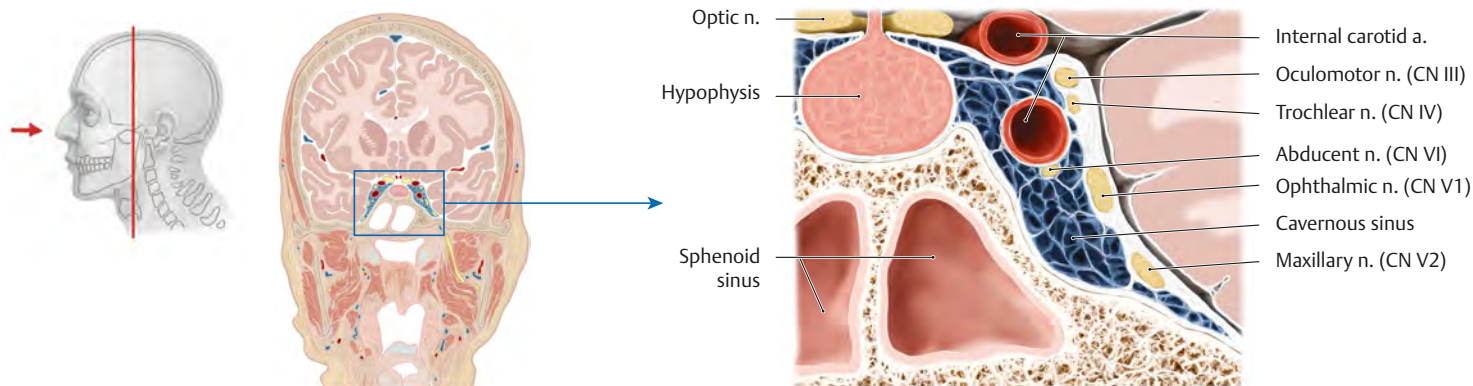


Fig. 41.19 Cavernous sinus, coronal section through middle cranial fossa

Anterior view. The right and left cavernous sinuses connect via the intercavernous sinuses that pass around the hypophysis, which sits in the hypophyseal fossa after invaginating the diaphragma sellae. On each side, this coronal section cuts through the internal carotid artery twice due to

the presence of the carotid siphon, a 180 degree bend in the cavernous part of the artery. Of the five cranial nerves, or their divisions, associated with the sinus only the abducent nerve (CN VI) is not embedded in the lateral dural wall.



Topography of the Superficial Face

Fig. 41.20 Superficial neurovasculature of the face

Anterior view. *Removed:* Skin and fatty subcutaneous tissue; muscles of facial expression (left side).

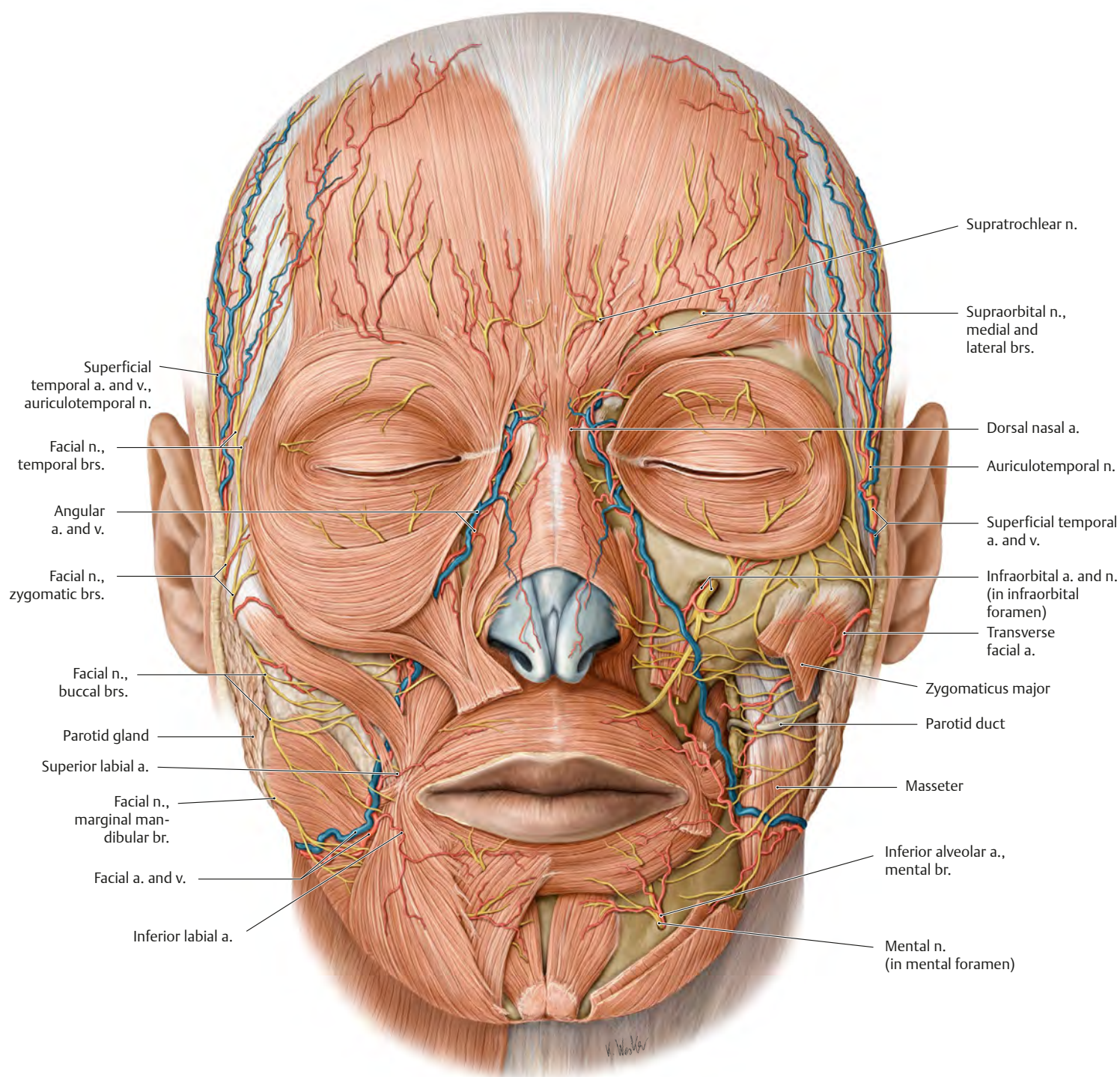
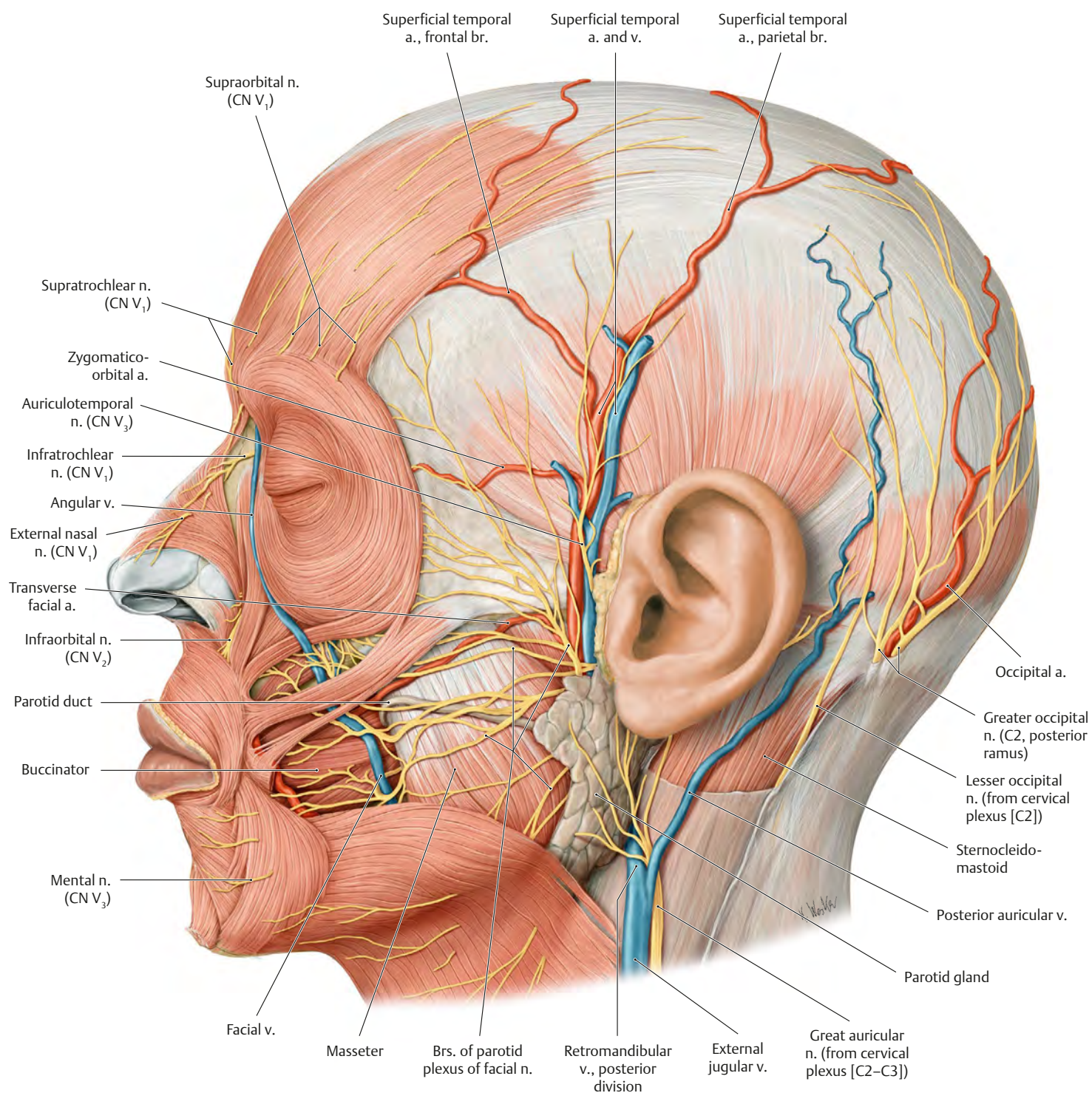


Fig. 41.21 Superficial neurovasculature of the head

Left lateral view.



Topography of the Parotid Region & Temporal Fossa

Fig. 41.22 Parotid region

Left lateral view. *Removed:* Parotid gland, sternocleidomastoid, and veins of the head.
Revealed: Parotid bed and carotid triangle.

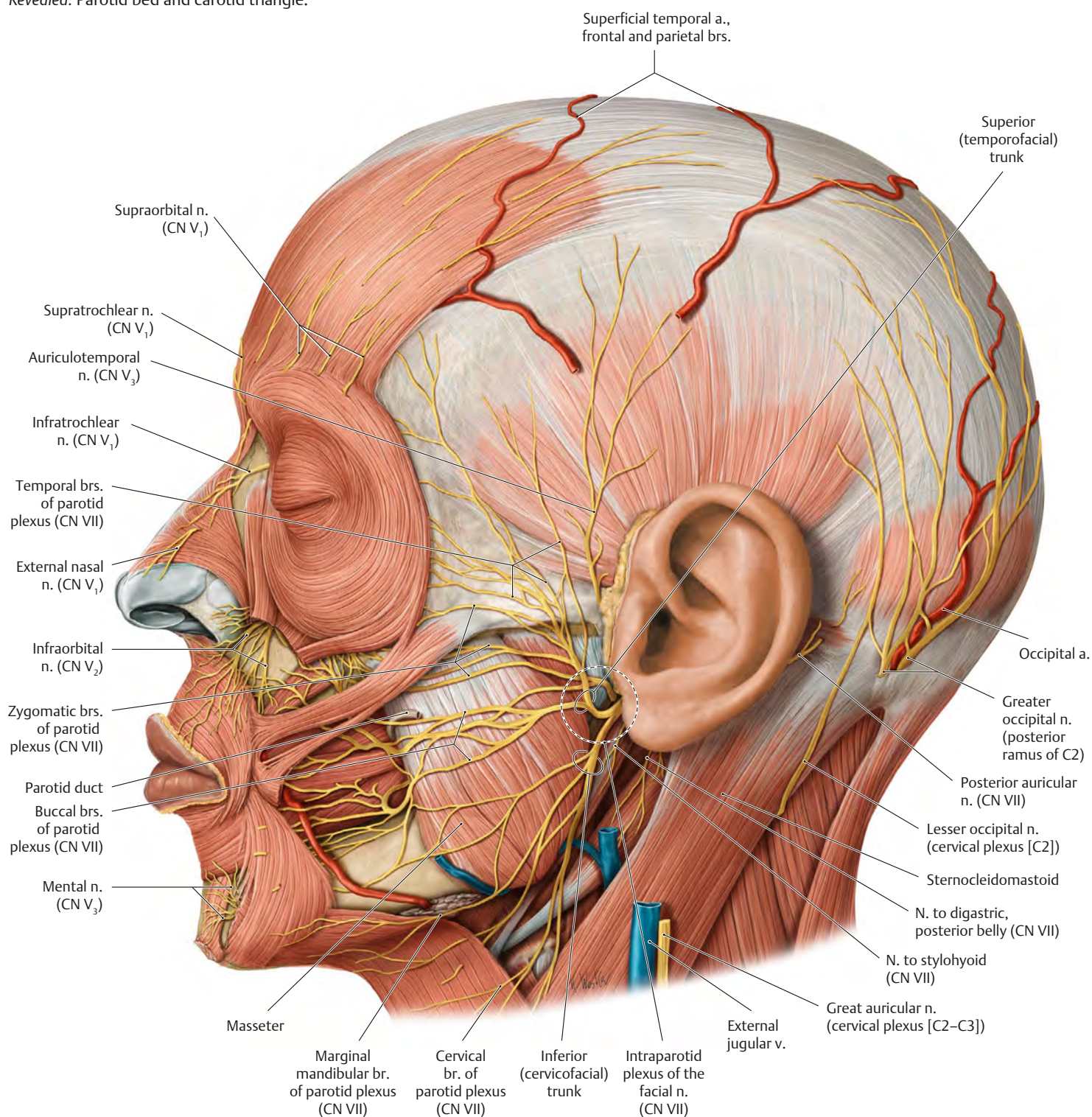
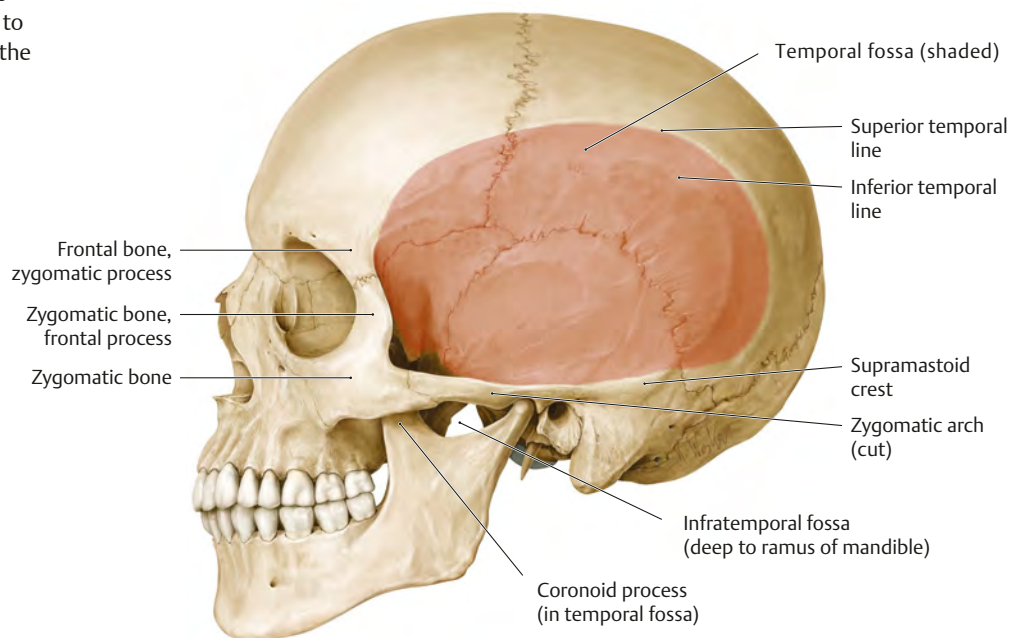
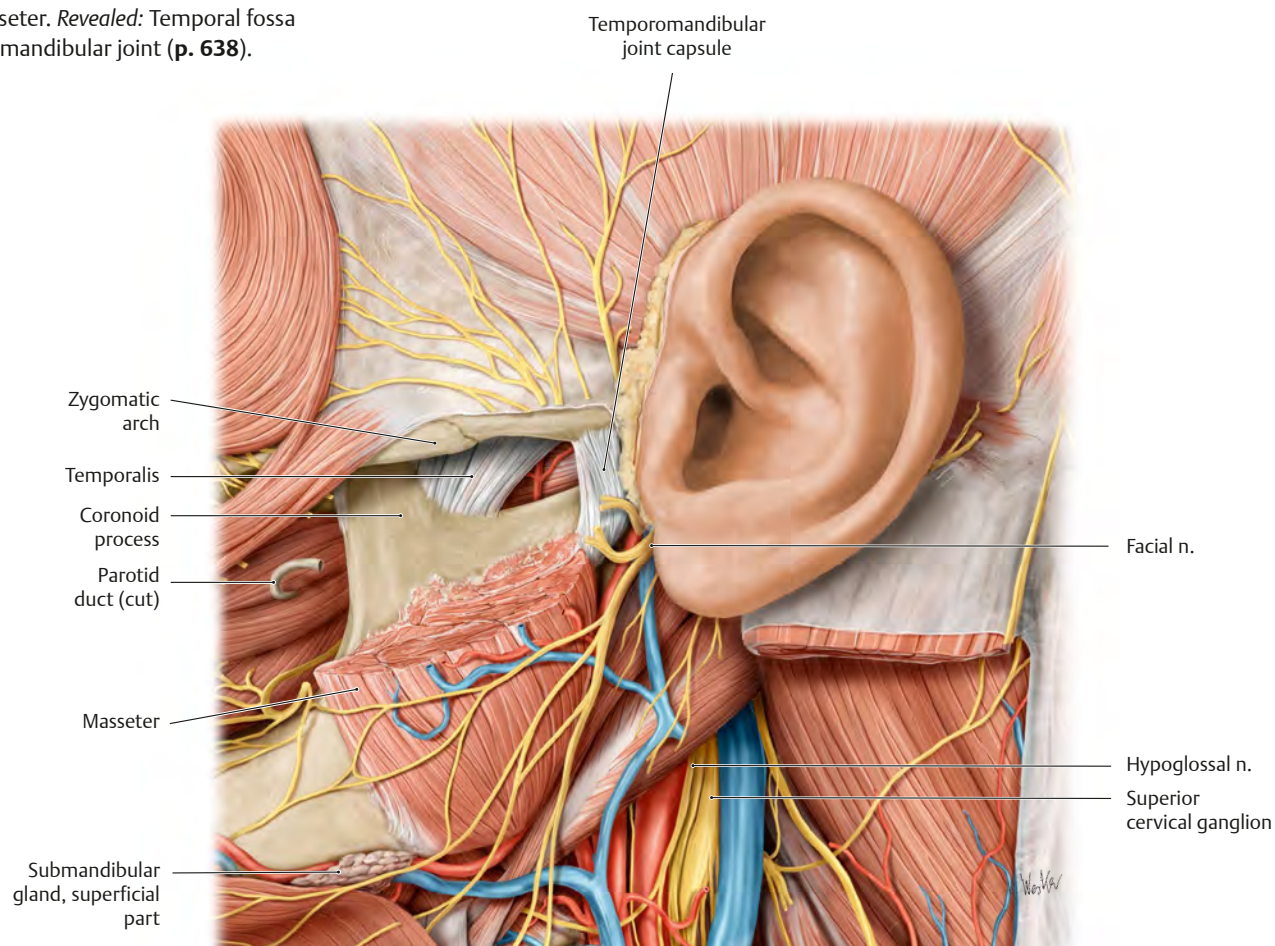


Fig. 41.23 Temporal fossa

Left lateral view. The temporal fossa is located on the lateral aspect of the skull. It communicates with the infratemporal fossa inferiorly (medial to the zygomatic arch). The main component of the fossa is the large temporalis muscle.

**Fig. 41.24 Temporal fossa**

Left lateral view. *Removed:* Sternocleidomastoid and masseter. *Revealed:* Temporal fossa and temporomandibular joint (p. 638).



Topography of the Infratemporal Fossa

Fig. 41.25 Bony boundaries of Infratemporal fossa

Oblique external view of base of the skull.

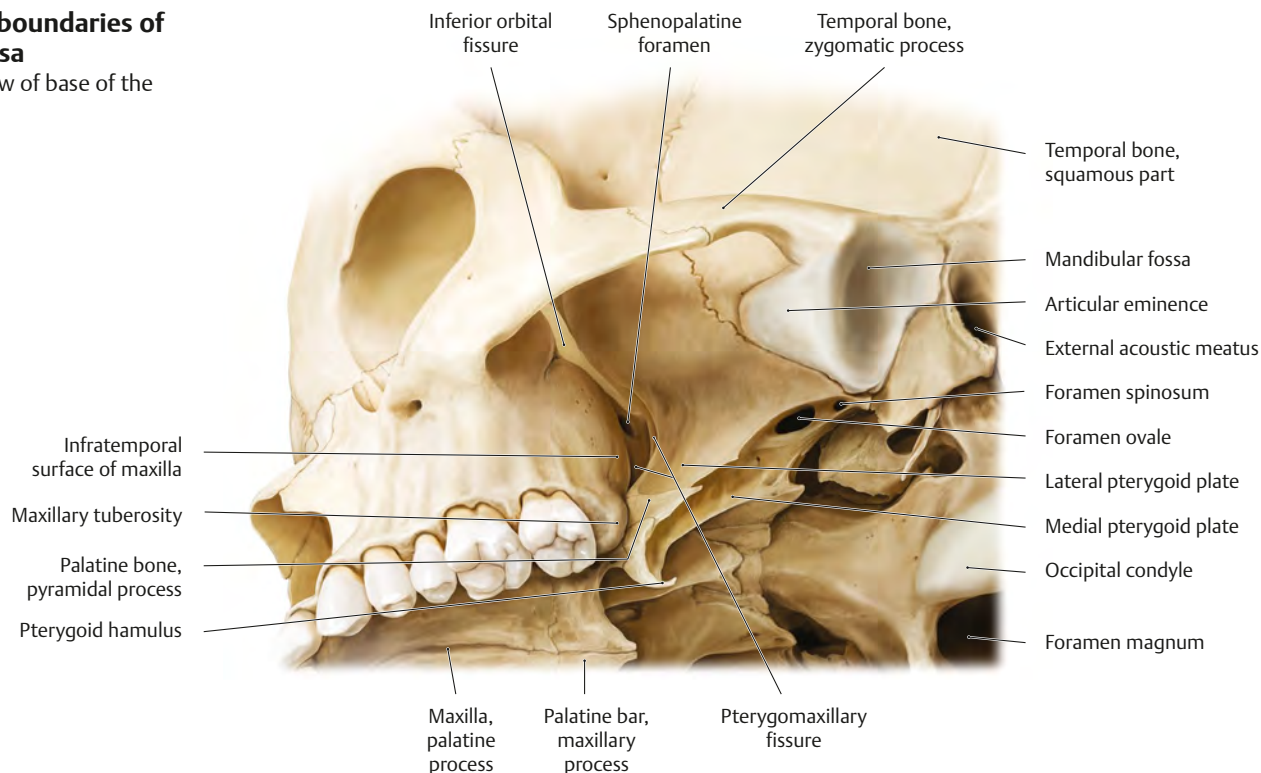


Fig. 41.26 Infratemporal fossa: Superficial dissection

Left lateral view. *Removed:* Ramus of mandible. *Note:* The mylohyoid nerve (see Fig. 45.15 and 45.17A) branches from the inferior alveolar nerve just before the mandibular foramen.

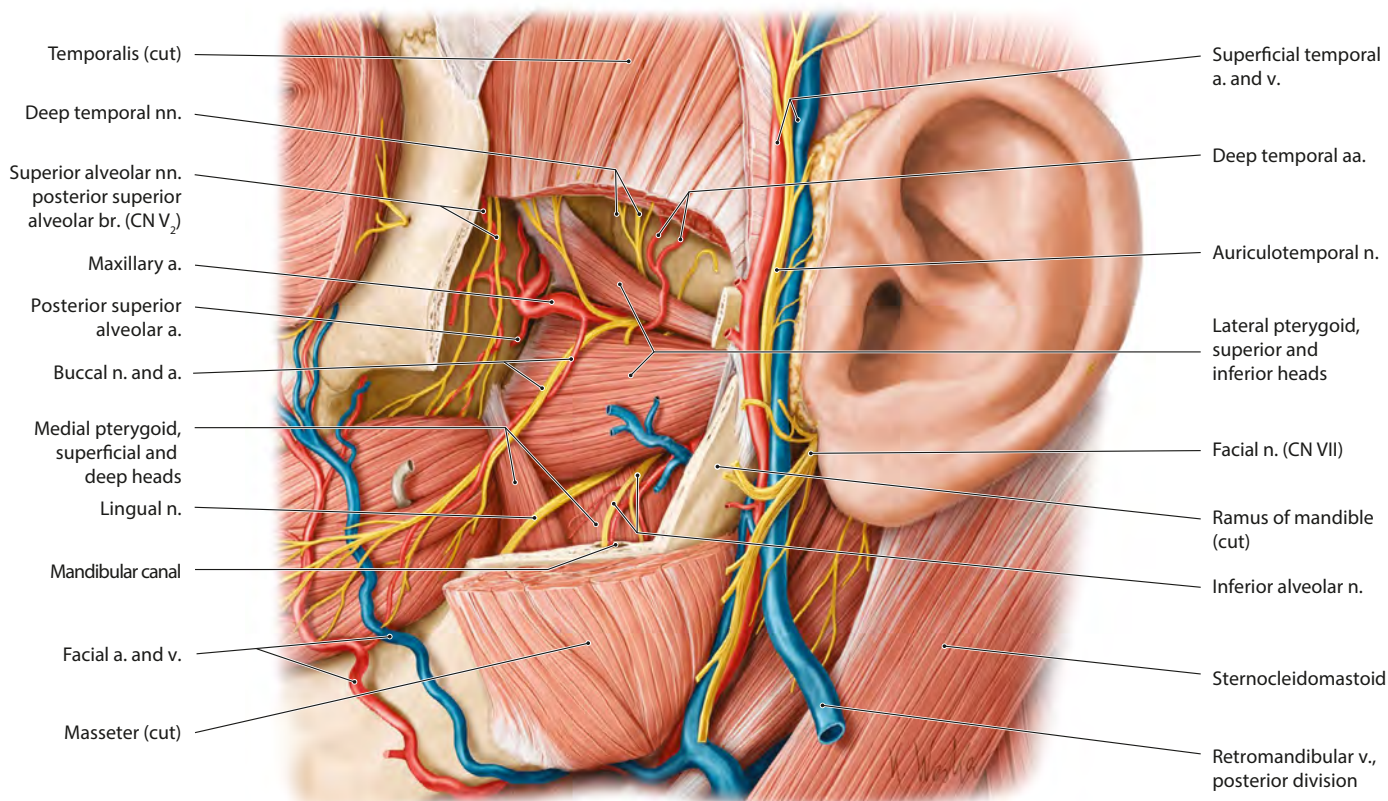
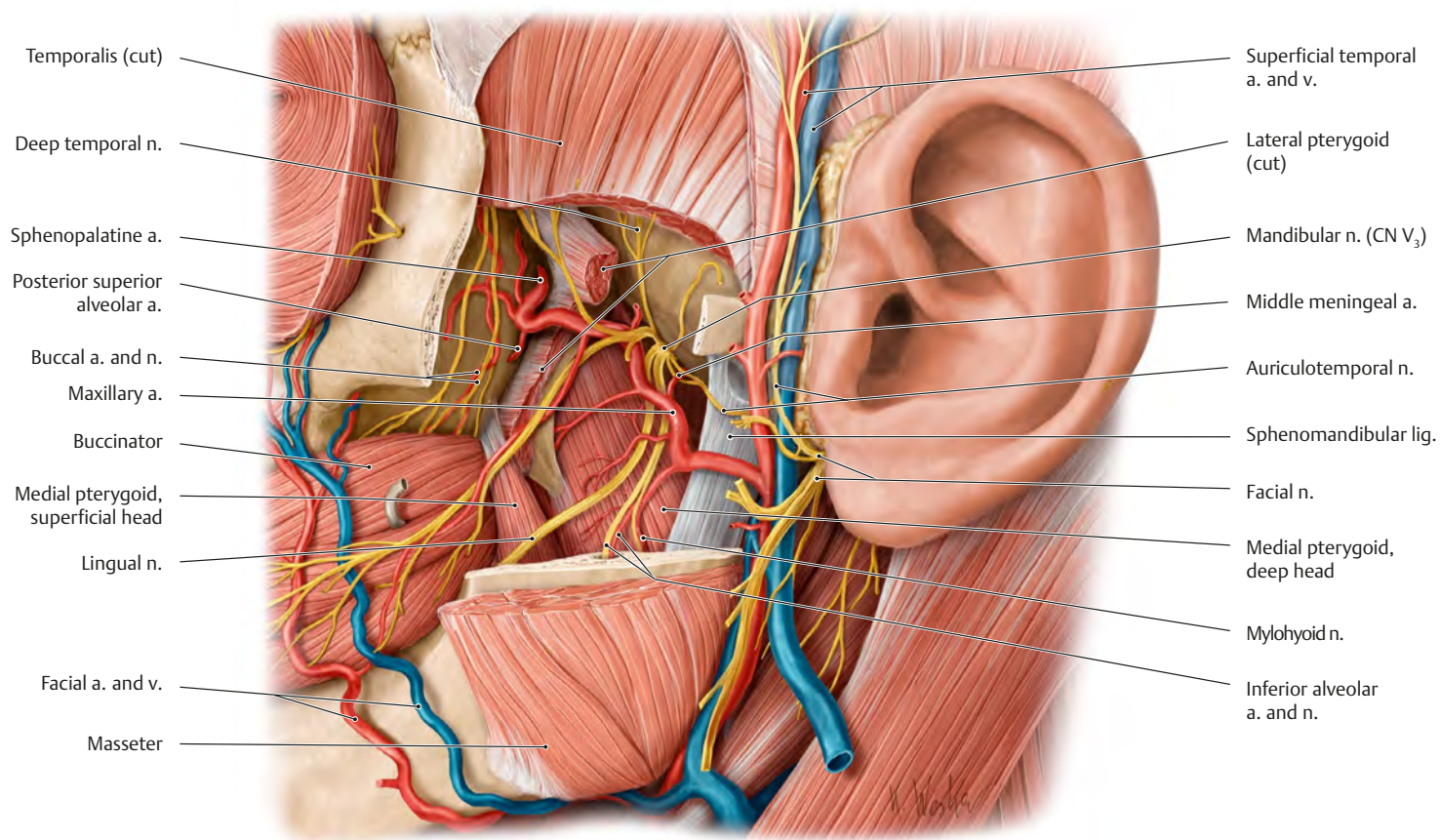


Fig. 41.27 Infratemporal fossa: Deep dissection

Left lateral view. *Removed:* Lateral pterygoid muscle (both heads).

Revealed: Deep infratemporal fossa and mandibular nerve as it enters the mandibular canal via the foramen ovale in the roof of the fossa.



Neurovasculature of the Infratemporal Fossa

Fig. 41.28 Mandibular nerve (CN V₃) in the infratemporal fossa

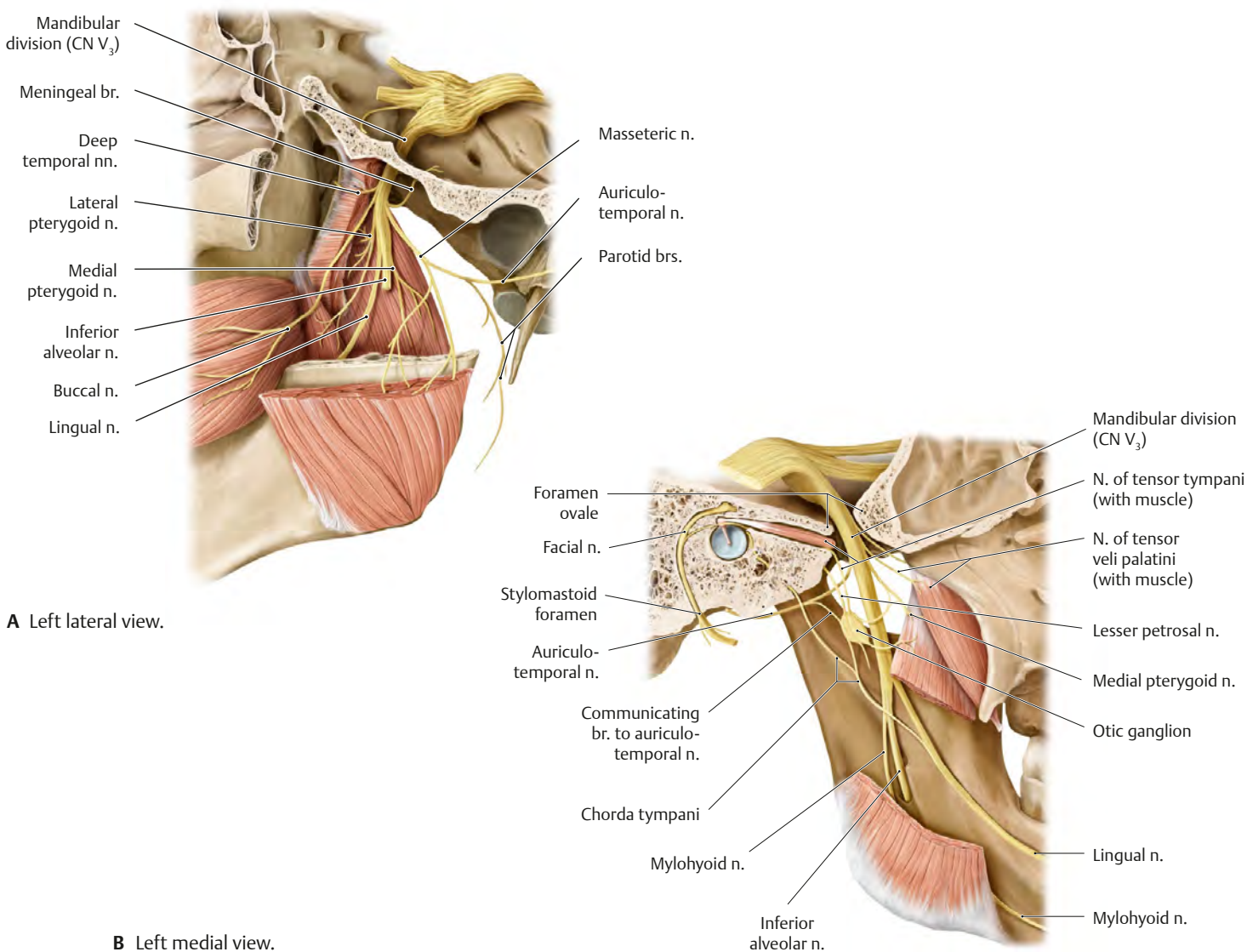


Table 41.7 Nerves of the infratemporal fossa		
Nerve	Nerve Fibers	Distribution
Muscular Branches (CN V ₃)	Branchial motor	Muscles of mastication; mylohyoid; tensor tympani; tensor veli palatini, anterior belly of digastric
Auriculotemporal (CN V ₃)	General sensory	Auricle, temporal region, and temporomandibular joint
	Visceral motor from glossopharyngeal n. (CN IX)	Parotid gland
Inferior alveolar (CN V ₃)	General sensory	Mandibular teeth; mental branch supplies skin of lower lip and chin
Lingual (CN V ₃)	General sensory	Anterior two thirds of tongue, floor of mouth
Buccal (CN V ₃)	General sensory	Skin and mucous membrane of cheek
Meningeal (CN V ₃)	General sensory	Dura of middle cranial fossa
Chorda tympani (CN VII)	Special sensory taste	Anterior two thirds of tongue
	Visceral motor	Submandibular and sublingual glands via submandibular ganglion and lingual n (CN V ₃)

Fig. 41.29 Arteries in the infratemporal fossa

Left lateral view into area. The maxillary artery passes either superficial or deep to the lateral pterygoid in the infratemporal fossa (see Fig. 41.27, p. 599) and passes medially into the pterygopalatine fossa through the pterygomaxillary fissure.

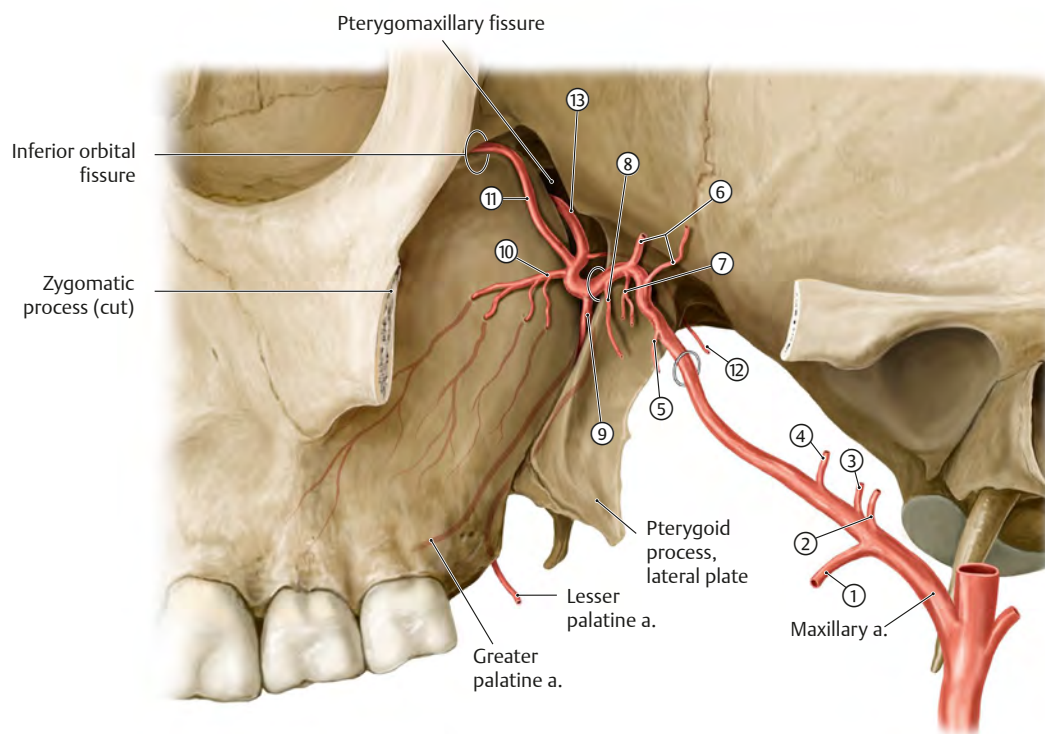


Table 41.8

Branches of the maxillary artery

Part	Artery		Distribution
Mandibular part (between the origin and the first circle around artery in Fig. 41.29)	① Inferior alveolar a.		Mandible, teeth, gingiva
	② Anterior tympanic a.		Tympanic cavity
	③ Deep auricular a.		Temporomandibular joint, external auditory canal
	④ Middle meningeal a.		Calvaria, dura, anterior and middle cranial fossae
Pterygoid part (between the first and second circles around the artery)	⑤ Masseteric a.		Masseter m.
	⑥ Deep temporal aa.		Temporalis m.
	⑦ Pterygoid brs.		Pterygoid mm.
	⑧ Buccal a.		Buccal mucosa
Pterygopalatine part (between the second and third circles around the artery)	⑨ Descending palatine a.	Greater palatine a.	Hard palate
		Lesser palatine a.	Soft palate, palatine tonsil, pharyngeal wall
	⑩ Posterior superior alveolar a.		Maxillary molars, maxillary sinus, gingiva
	⑪ Infraorbital a.		Maxillary alveoli
	⑫ A. of pterygoid canal		
	⑬ Sphenopalatine a.	Lateral posterior nasal aa.	Lateral wall of nasal cavity, choanae
		Posterior septal brs.	Nasal septum

42 Orbit & Eye Bones of the Orbit

Fig. 42.1 Bones of the orbit

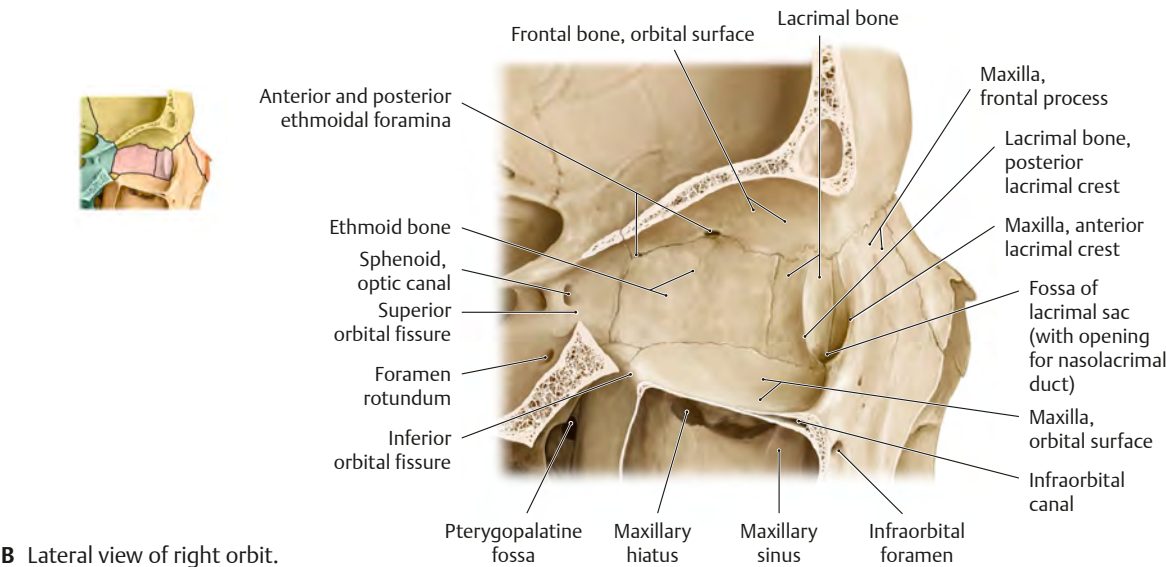
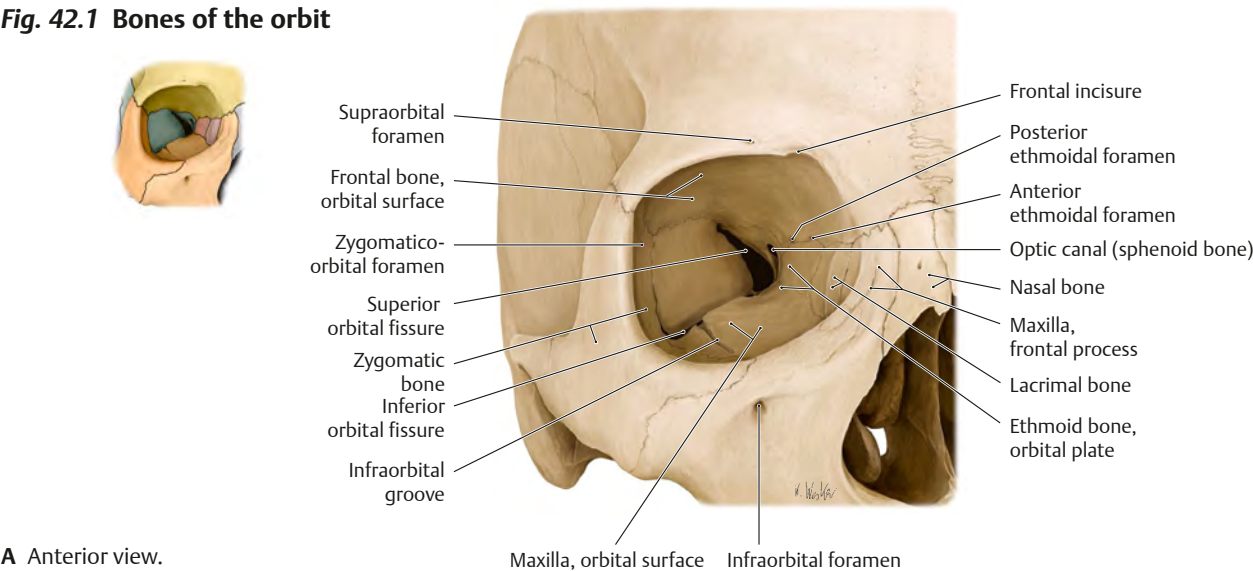


Table 42.1				Openings in the orbit for neurovascular structures	
Opening*		Nerves		Vessels	
Optic canal		Optic n. (CN II)		Ophthalmic a.	
Superior orbital fissure		Oculomotor n. (CN III) Trochlear n. (CN IV) Abducent n. (CN VI)	Trigeminal n., ophthalmic division (CN V ₁) • Lacrimal n. • Frontal n. • Nasociliary n.	Superior ophthalmic v.	
Inferior orbital fissure		Infraorbital n. (CN V ₂) Zygomatic n. (CN V ₂)		Infraorbital a. and v., inferior ophthalmic v.	
Infraorbital canal		Infraorbital n. (CN V ₂), a., and v.			
Supraorbital foramen		Supraorbital n. (lateral br.)		Supraorbital a.	
Frontal incisure		Supraorbital n. (medial br.)		Supratrochlear a.	
Anterior ethmoidal foramen		Anterior ethmoidal n., a., and v.			
Posterior ethmoidal foramen		Posterior ethmoidal n., a., and v.			
* The nasolacrimal canal transmits the nasolacrimal duct.					

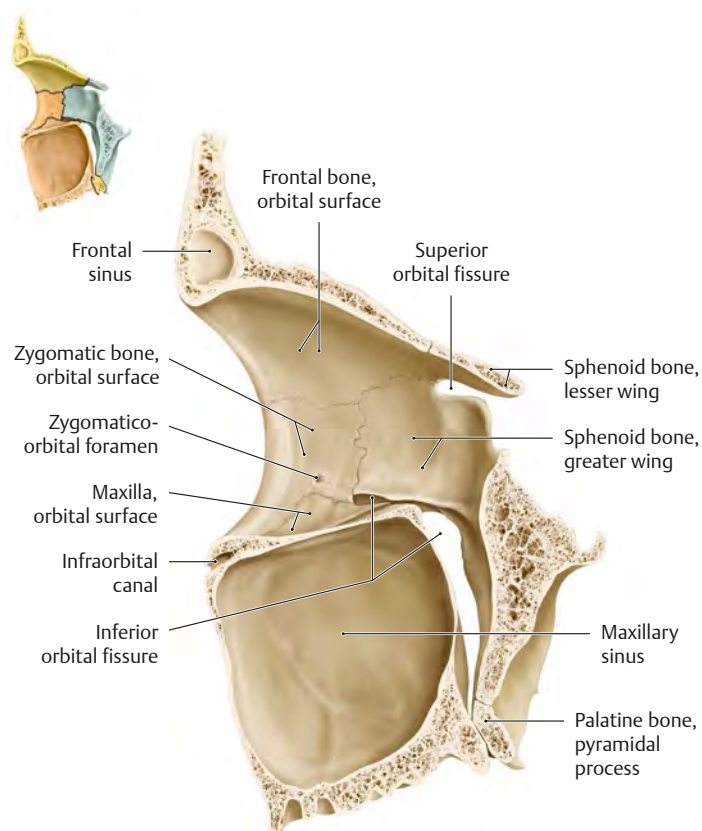
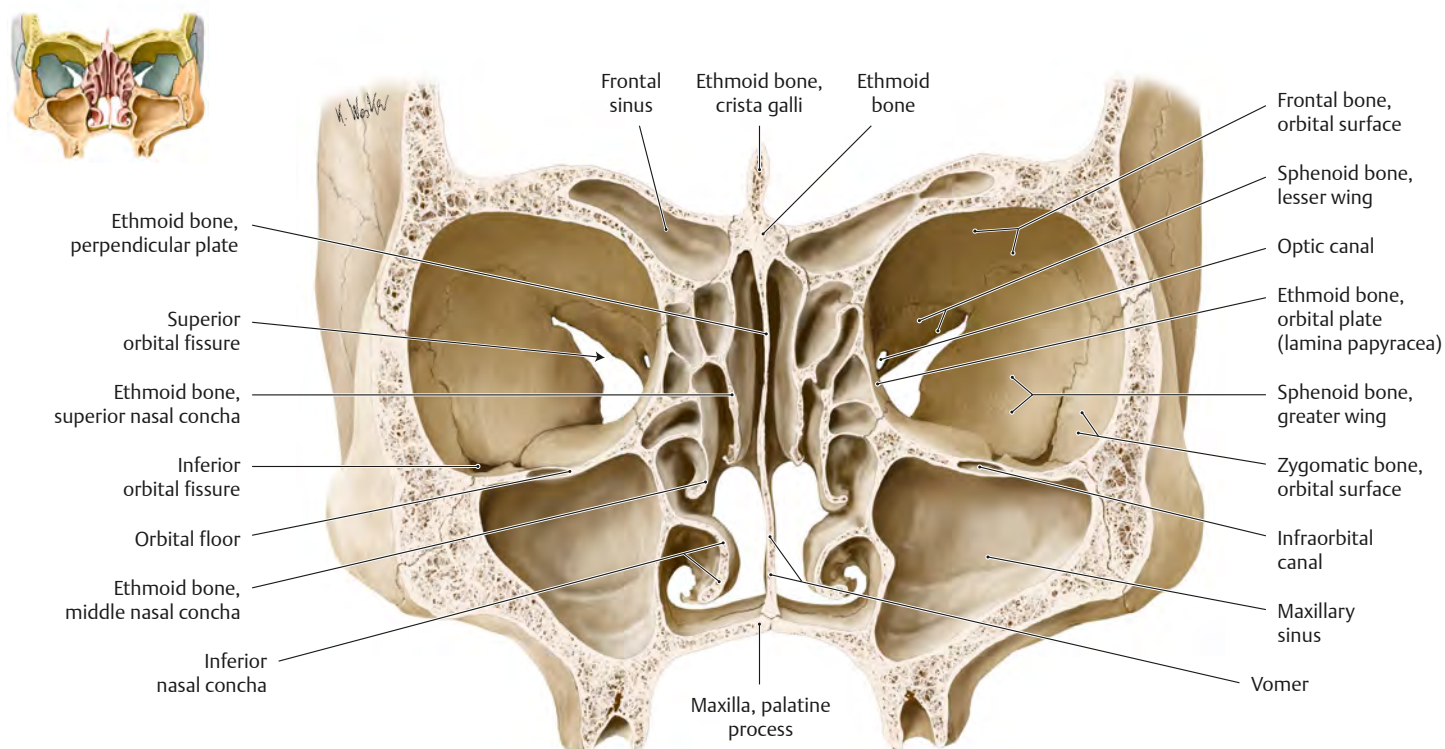


Table 42.2

Structures surrounding the orbit

Direction	Bordering structure
Superior	Frontal sinus
	Anterior cranial fossa
Medial	Ethmoid sinus
Inferior	Maxillary sinus
Certain deeper structures also have a clinically important relationship to the orbit:	
Sphenoid sinus	Hypophysis (pituitary)
Middle cranial fossa	Cavernous sinus
Optic chiasm	Pterygopalatine fossa

C Medial view of right orbit.



D Coronal section, anterior view.

Muscles of the Orbit

Fig. 42.2 Extraocular muscles

The eyeball is moved by six extrinsic muscles: four rectus (superior, inferior, medial, and lateral) and two oblique (superior and inferior).

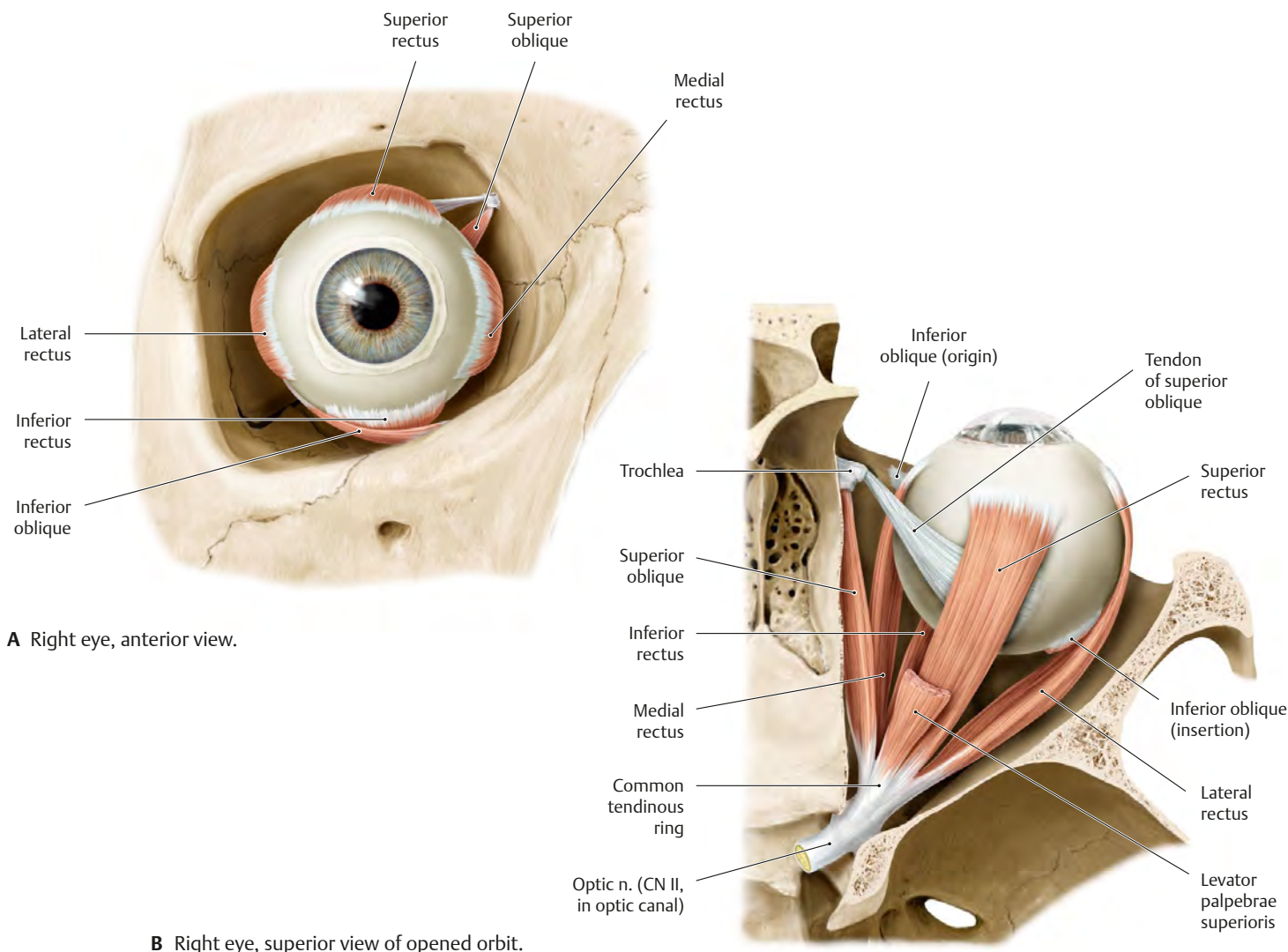


Fig. 42.3 Testing the extraocular muscles

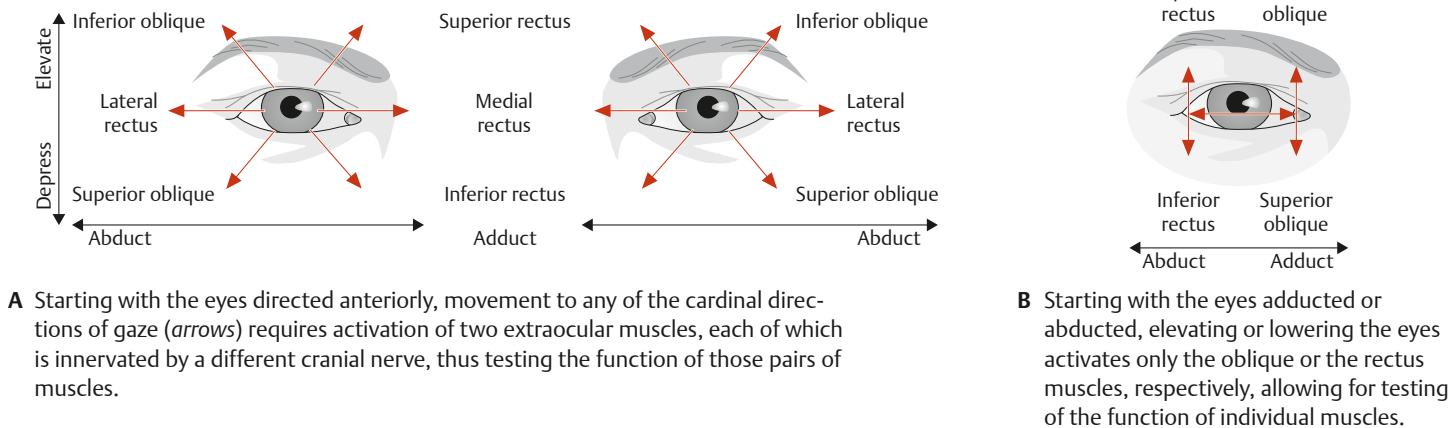
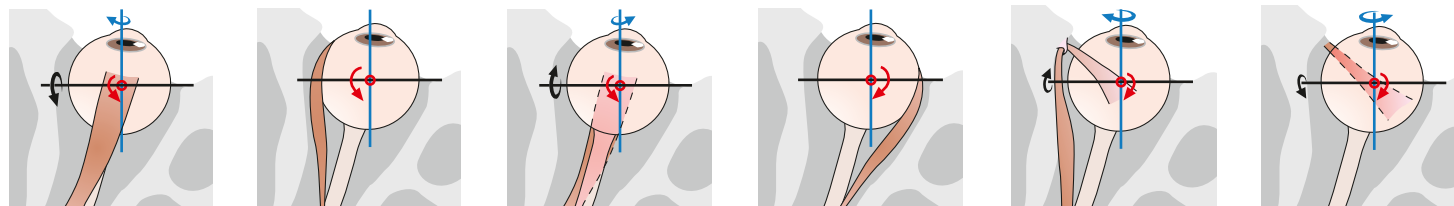


Fig. 42.4 Actions of the extraocular muscles

Superior view of opened orbit. Vertical axis, red circle; horizontal axis, black; anteroposterior (visual/optical) axis, blue.

**A** Superior rectus.**B** Medial rectus.**C** Inferior rectus.**D** Lateral rectus.**E** Superior oblique.**F** Inferior oblique.**Table 42.3** Extraocular muscles

Muscle	Origin	Insertion	Action (see Fig. 42.4)*			Innervation
			Vertical axis (red)	Horizontal axis (black)	Anteroposterior axis (blue)	
Superior rectus	Common tendinous ring (common annular tendon)	Sclera of the eye	Elevates	Adducts	Rotates medially	Oculomotor n. (CN III), superior branch
Medial rectus			—	Adducts	—	Oculomotor n. (CN III), inferior branch
Inferior rectus			Depresses	Adducts	Rotates laterally	
Lateral rectus			—	Abducts	—	Abducent n. (CN VI)
Superior oblique	Sphenoid bone*		Depresses	Abducts	Rotates medially	Trochlear n. (CN IV)
Inferior oblique	Medial orbital margin		Elevates	Abducts	Rotates laterally	Oculomotor n. (CN III), inferior branch

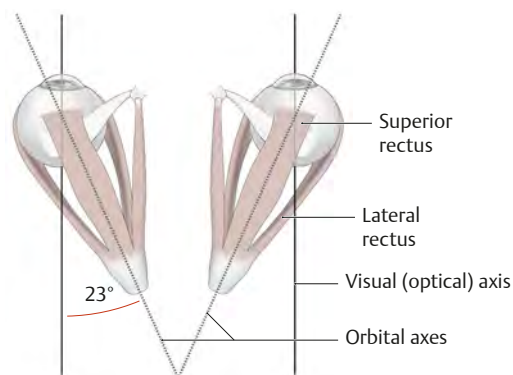
* Starting from gaze directed anteriorly

* The tendon of the superior oblique passes through a tendinous loop (trochlea) attached to the superomedial orbital margin.

**Clinical box 42.1****Oculomotor palsies**

Oculomotor palsies may result from a lesion involving an eye muscle or its associated cranial nerve (at the nucleus or along the course of the nerve). If one extraocular muscle is weak or paralyzed, deviation of the eye will be noted.

Impairment of the coordinated actions of the extraocular muscles may cause the visual axis of one eye to deviate from its normal position. The patient will therefore perceive a double image (diplopia).

**A** Abducent nerve palsy. Disabled: Lateral rectus.**B** Trochlear nerve palsy. Disabled: Superior oblique.**C** Complete oculomotor palsy. Disabled: Superior, inferior, and medial recti and inferior oblique.**D** Normal visual and orbital axes.

Neurovasculature of the Orbit

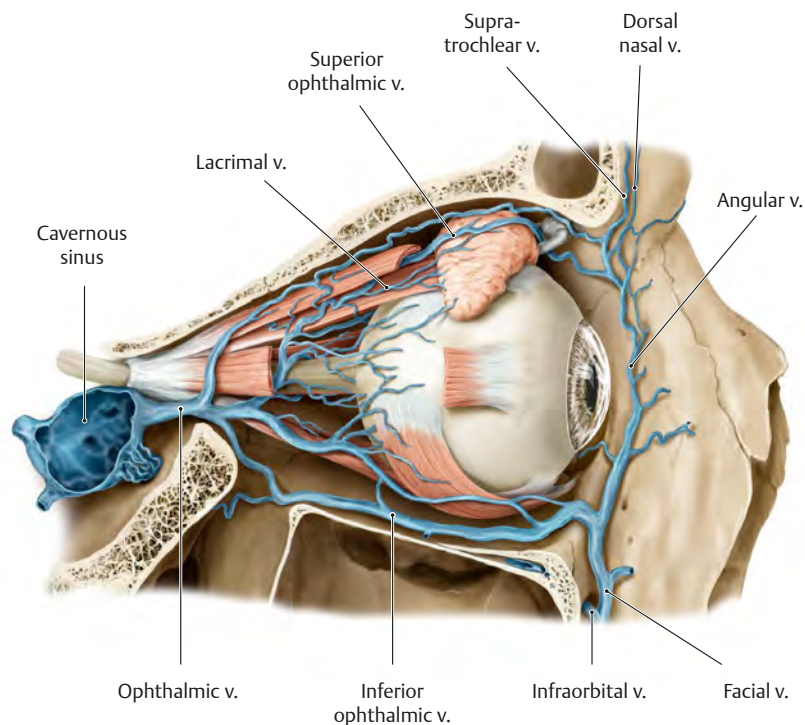
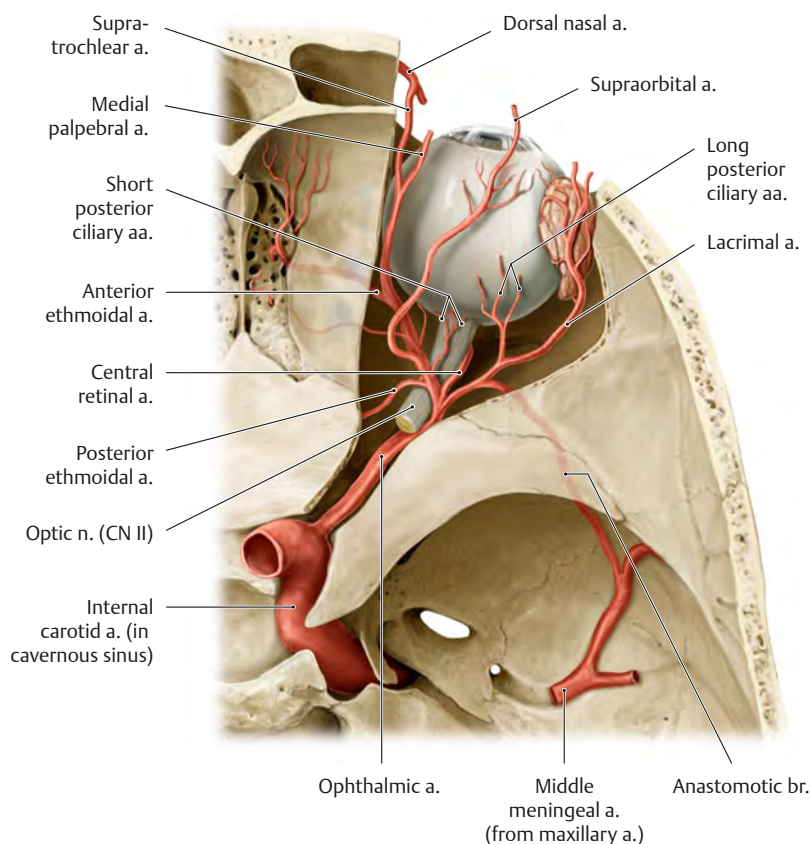


Fig. 42.5 Veins of the orbit

Lateral view of the right orbit. *Removed:* Lateral orbital wall. *Opened:* Maxillary sinus.

Fig. 42.6 Arteries of the orbit

Superior view of the right orbit. *Opened:* Optic canal and orbital roof.



Clinical box 42.2

Cavernous sinus syndrome

Gravity allows venous blood from the danger triangle region of the face (see figure) to drain to the cavernous sinus via the valveless ophthalmic veins. Squeezing a pimple or boil in this facial region can result in infectious thrombi being forced into the venous system and passing back into the cavernous sinus. Cavernous sinus syndrome (CIS) is diagnosed by the loss of eyeball movement due to the various cranial nerves associated with the cavernous sinus becoming infected.

The abducent nerve (CN VI) is bathed in blood within the sinus, the first ocular movement to be affected is lateral deviation of the eyeball. The oculomotor (CN III) and trochlear (CN IV) nerves, embedded in the dural lateral wall of the sinus are also eventually affected as the infection penetrates the dura. The eyeball becomes frozen in the orbit as all nerves activating the extraocular mm. become infected. CN V₁ is also in the lateral dural wall so a tingling/parasthesia is felt in the sensory region covered (forehead). Occasionally CN V₂ may also be involved and this parasthesia may also extend to the skin of the face below the orbit. The intercavernous sinuses allow the infection to spread to the cavernous sinus on the opposite side. If left untreated, death can result however cavernous sinus septic thrombophlebitis mortality has decreased from 100% to 20% with the of improvements in diagnosis and treatment.

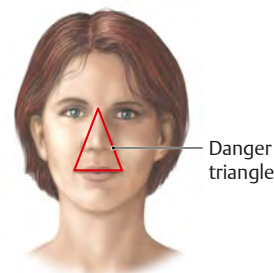
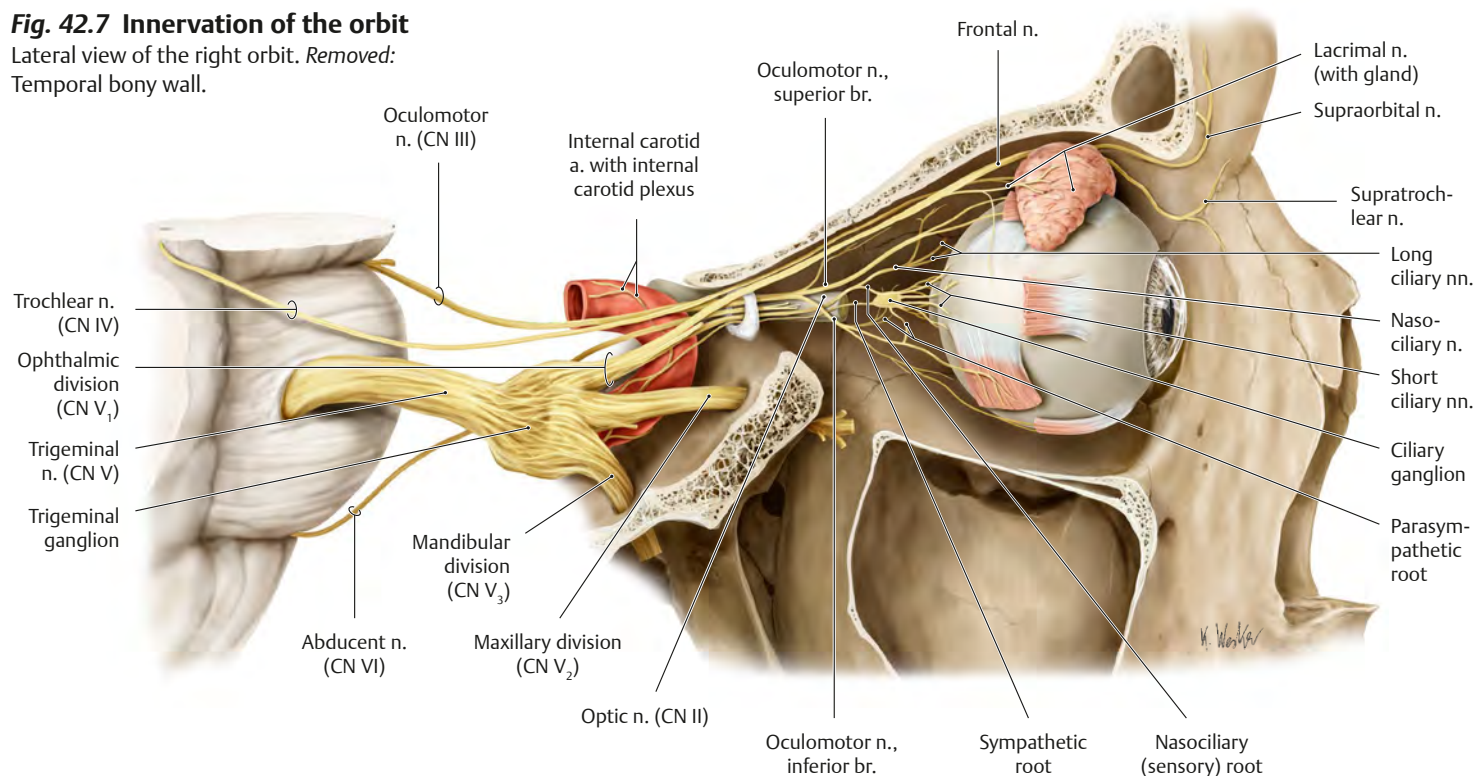


Fig. 42.7 Innervation of the orbit

Lateral view of the right orbit. *Removed:* Temporal bony wall.

**Fig. 42.8 A course of the cranial nerves through the cavernous sinus toward the orbit**

Sella turcica with partially opened cavernous sinus on the right side, cranial view.

The trigeminal ganglia are displayed on both sides. The right ganglion is pulled laterally from its normal position (thereby exposing the trigeminal cave = Meckel's cave) to show the cavernous sinus and the internal carotid artery, which passes through the sinus.

Note the abducent nerve also traverses the cavernous sinus and runs lateral to the carotid artery. All other nerves (oculomotor, trochlear and the three branches of the trigeminal) run rostrally and caudally in the

lateral dural wall of the cavernous sinus. Most cases of intracavernous carotid aneurysm only involve the abducent nerve. The space-occupying aneurysm compresses the nerve, causing a loss of function. In cases with sudden onset of isolated abducent nerve palsy, carotid aneurysm should always be considered as a possible cause. In contrast, isolated trochlear nerve palsy is rare. More often, the trochlear nerve is one of multiple nerves affected, e.g. in cases of cavernous sinus thrombosis which involves all nerves traveling through the cavernous sinus, often affecting also both branches of the trigeminal nerve.

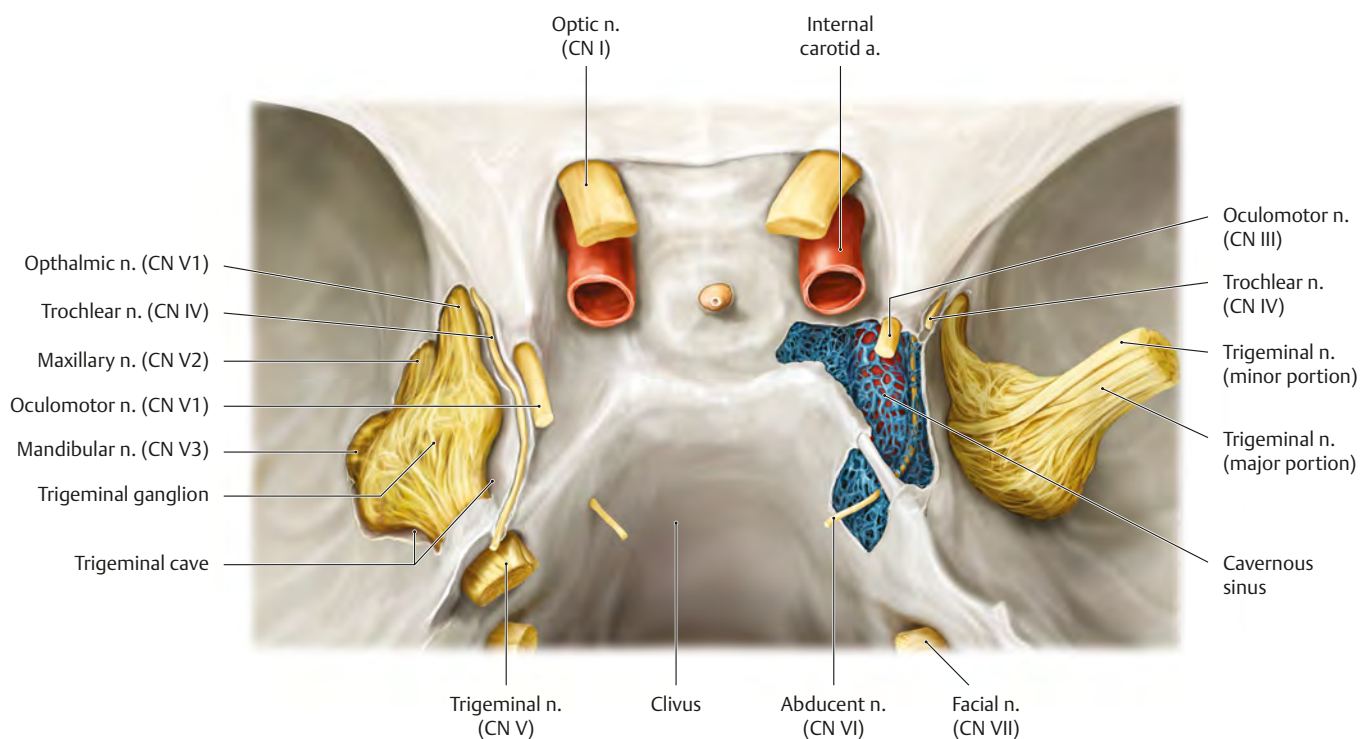


Fig. 42.9 Neurovascular structures of the orbit

Anterior view. *Right side:* Orbicularis oculi removed. *Left side:* Orbital septum partially removed.

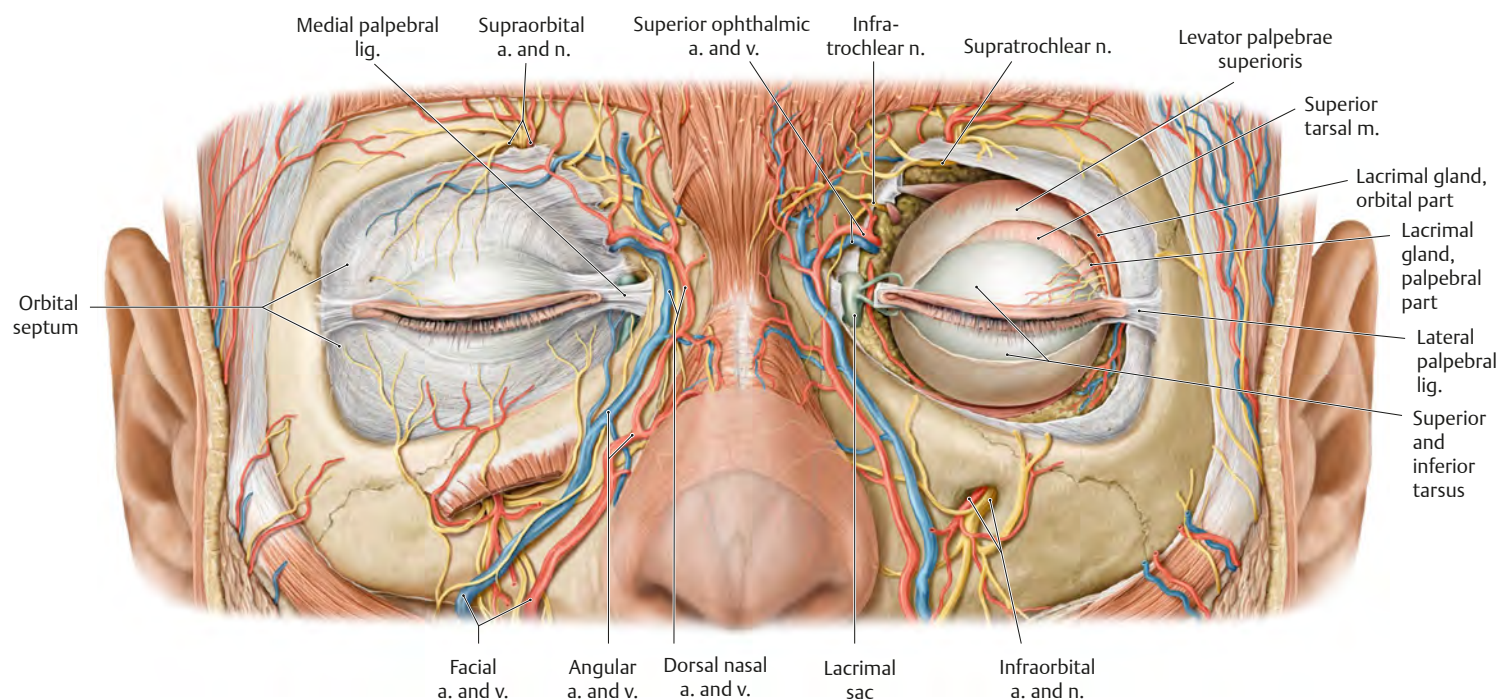


Fig. 42.10 Passage of neurovascular structures through the orbit

Anterior view. *Removed:* Orbital contents. *Note:* The optic nerve and ophthalmic artery travel in the optic canal. The remaining structures pass through the superior orbital fissure.

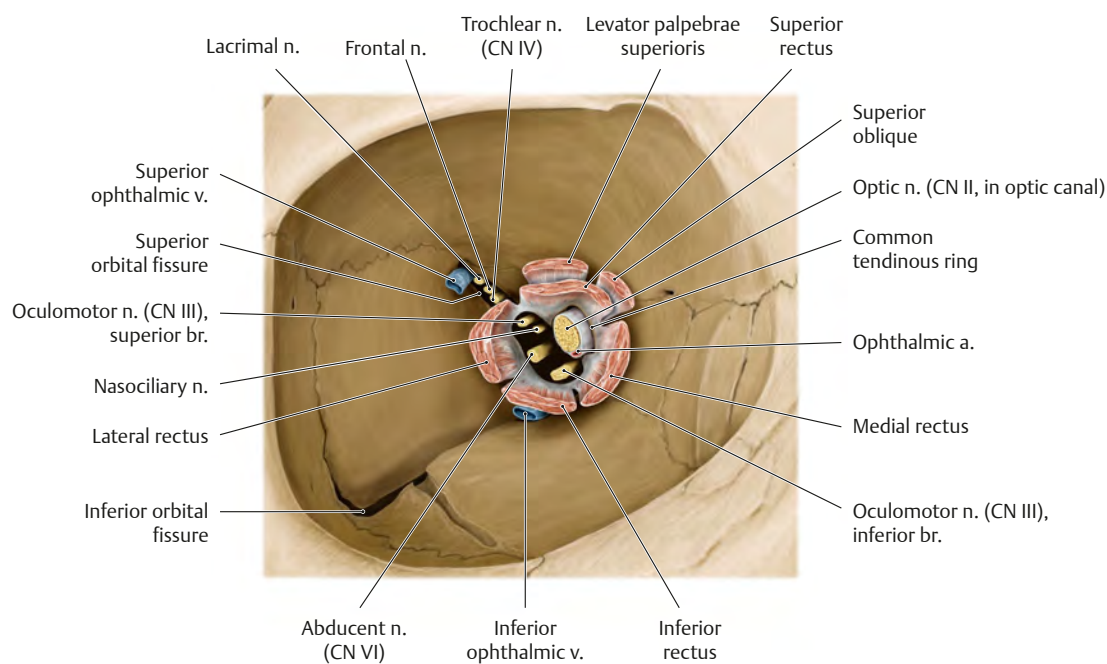
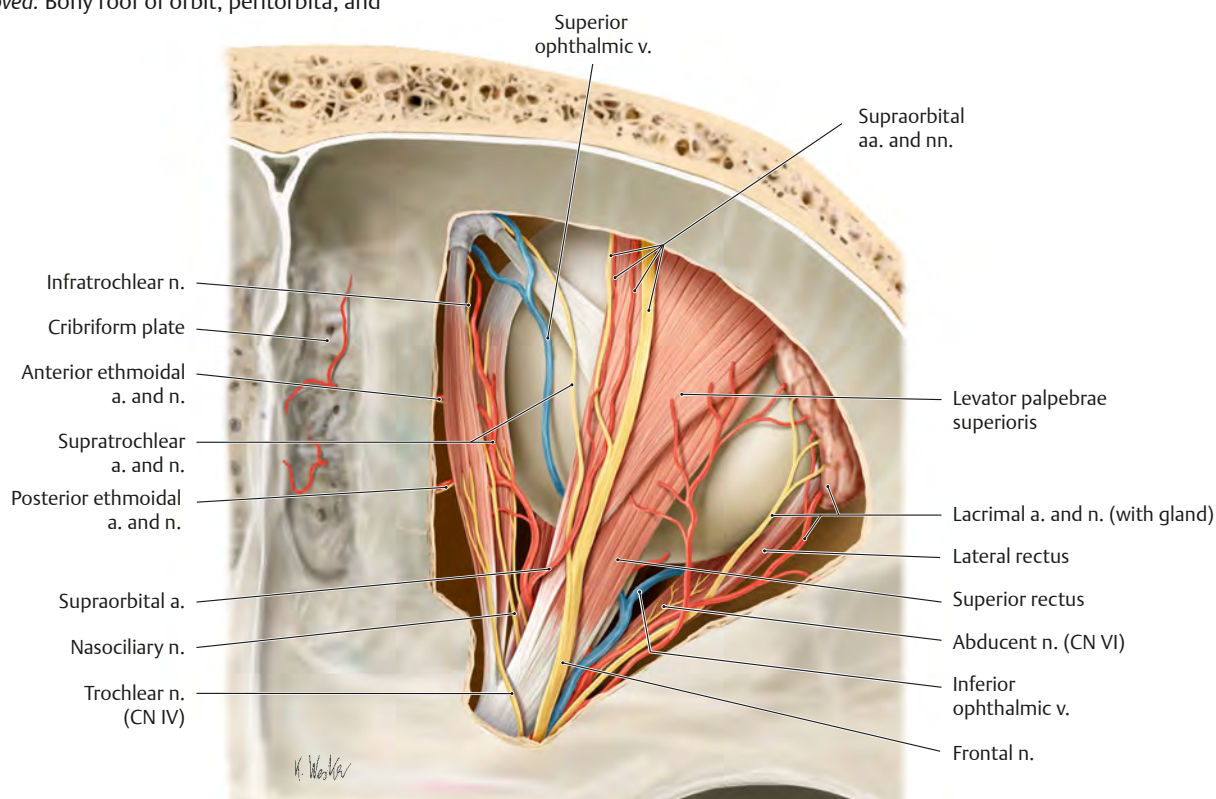
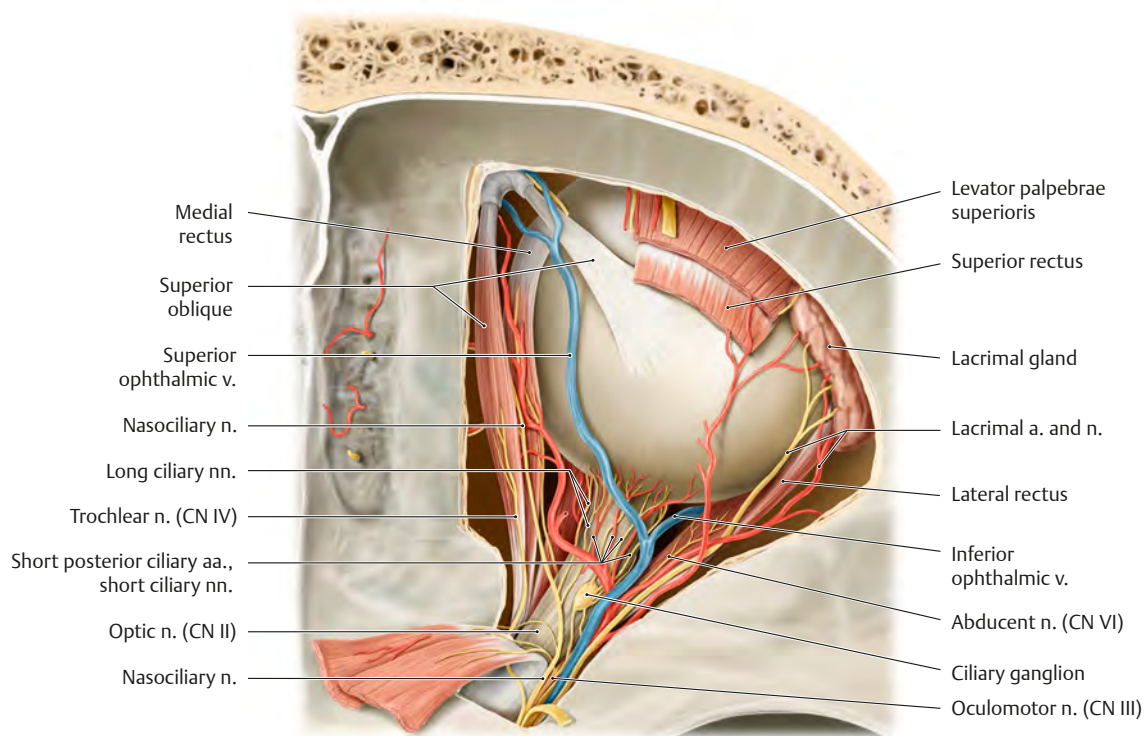


Fig. 42.11 Neurovascular contents of the orbit

Superior view. *Removed:* Bony roof of orbit, periorbita, and retro-orbital fat.



A Upper level.



B Middle level. *Reflected:* Levator palpebrae superioris and superior rectus. *Revealed:* Optic nerve.

Orbit & Eyelid

Fig. 42.12 Topography of the orbit

Sagittal section through the right orbit, medial view.

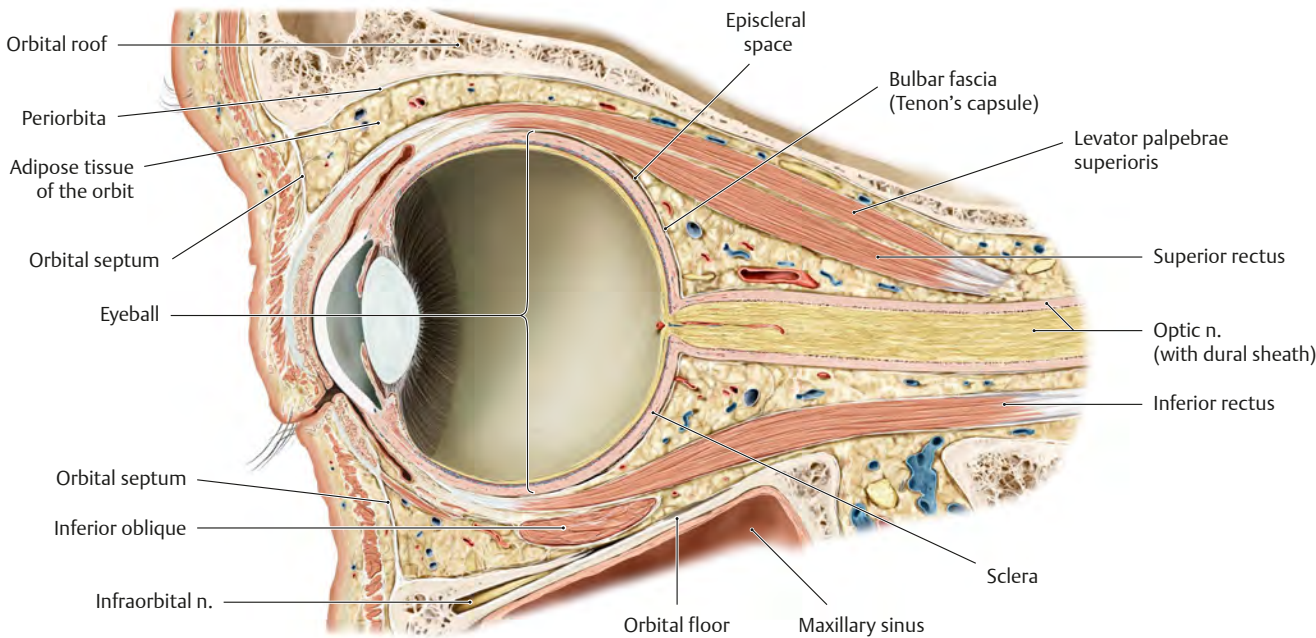


Fig. 42.13 Eyelids and conjunctiva

Sagittal section through the anterior orbital cavity.

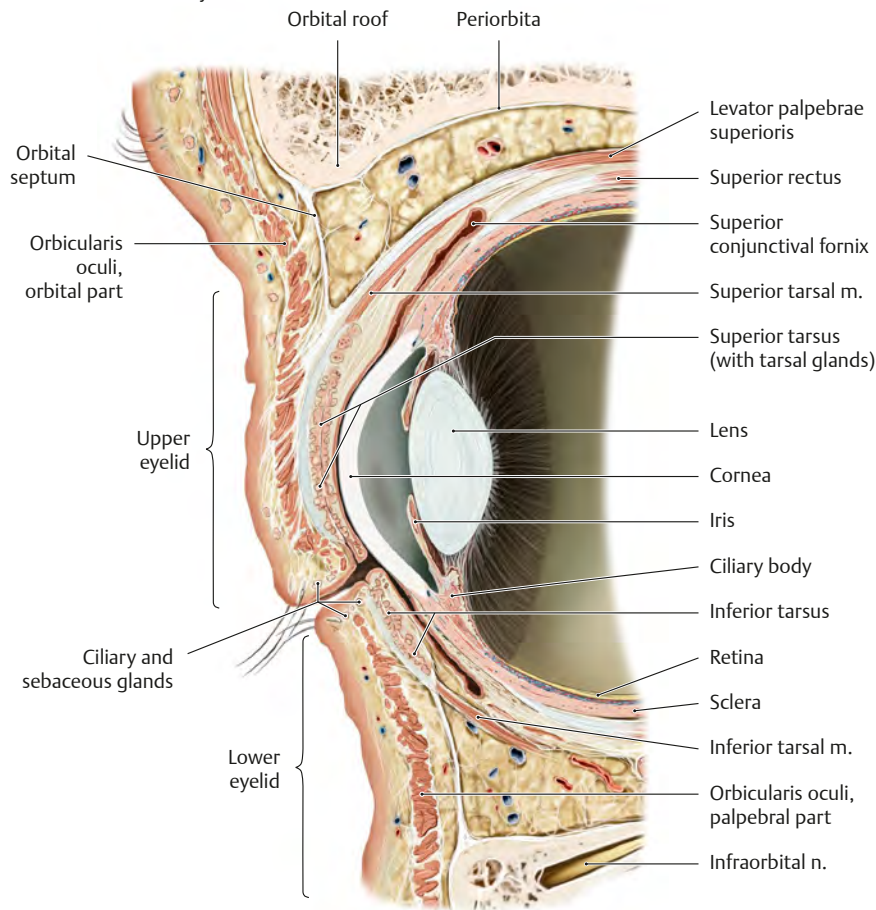
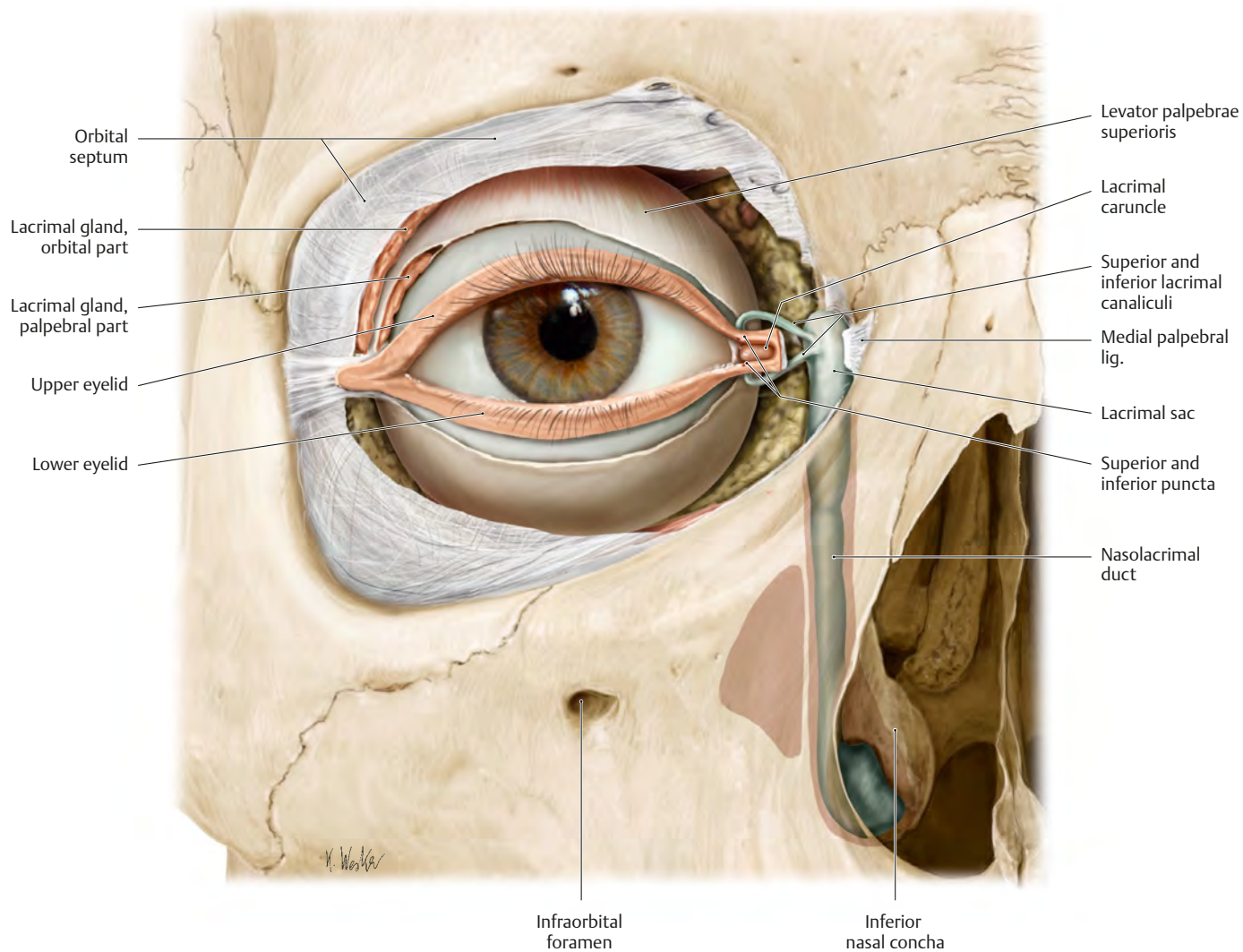


Fig. 42.14 Lacrimal apparatus

Right eye, anterior view. *Removed:* Orbital septum (partial). *Divided:* Levator palpebrae superioris (tendon of insertion).

**Clinical box 42.3****Lacrimal drainage**

Perimenopausal women are frequently subject to chronically dry eyes (*keratoconjunctivitis sicca*), due to insufficient tear production by the lacrimal gland. Acute inflammation of the lacrimal gland (due to bacteria) is less common and characterized by intense inflammation and extreme tenderness to palpation. The upper eyelid shows a characteristic S-curve.



Eye

Fig. 42.15 Structure of the eyeball

Transverse section through right eyeball, superior view. *Note:* The orbital axis (running along the optic nerve through the optic disk) deviates from the optical axis (running through the center of the eye to the fovea centralis) by 23 degrees.

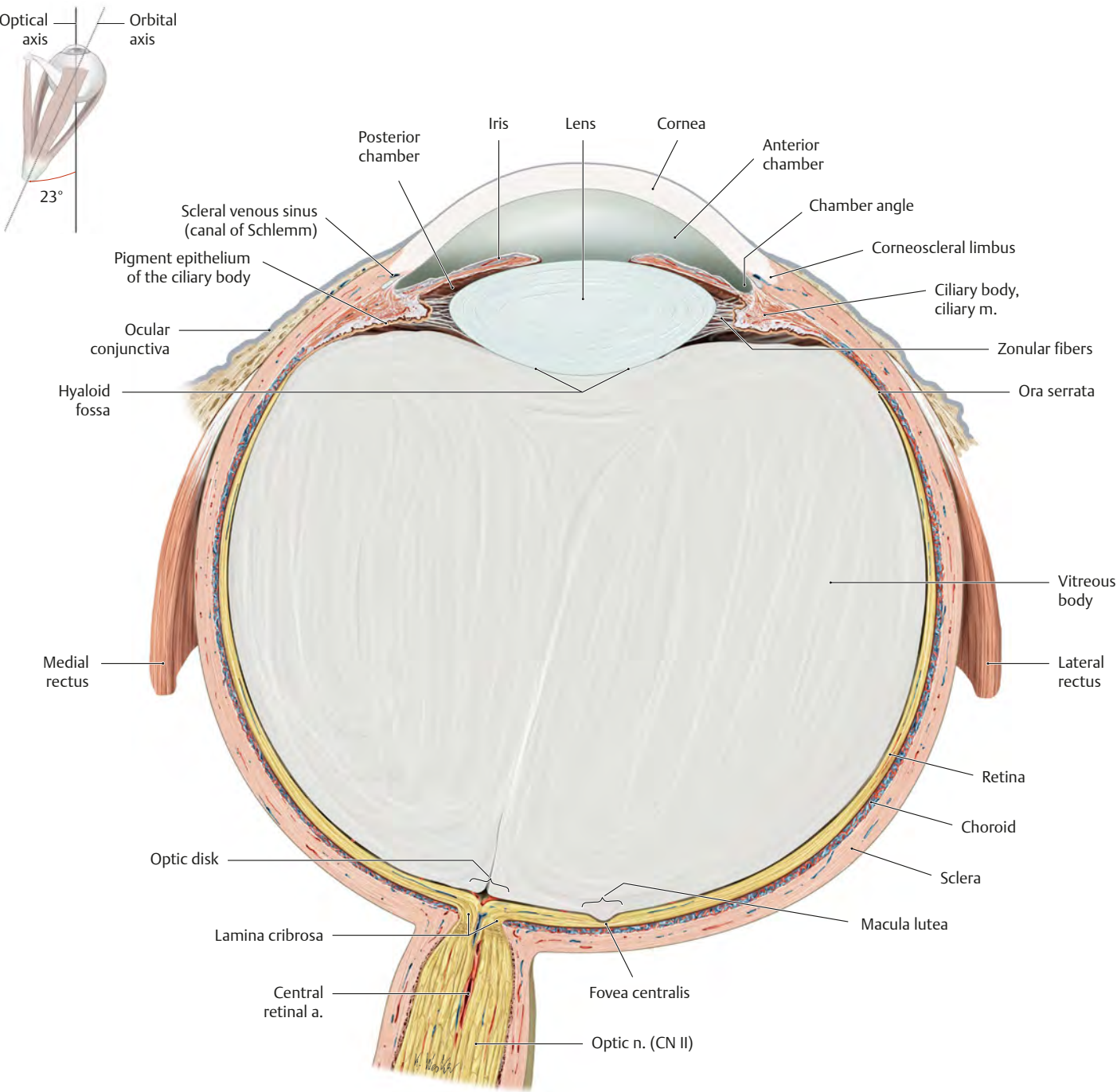
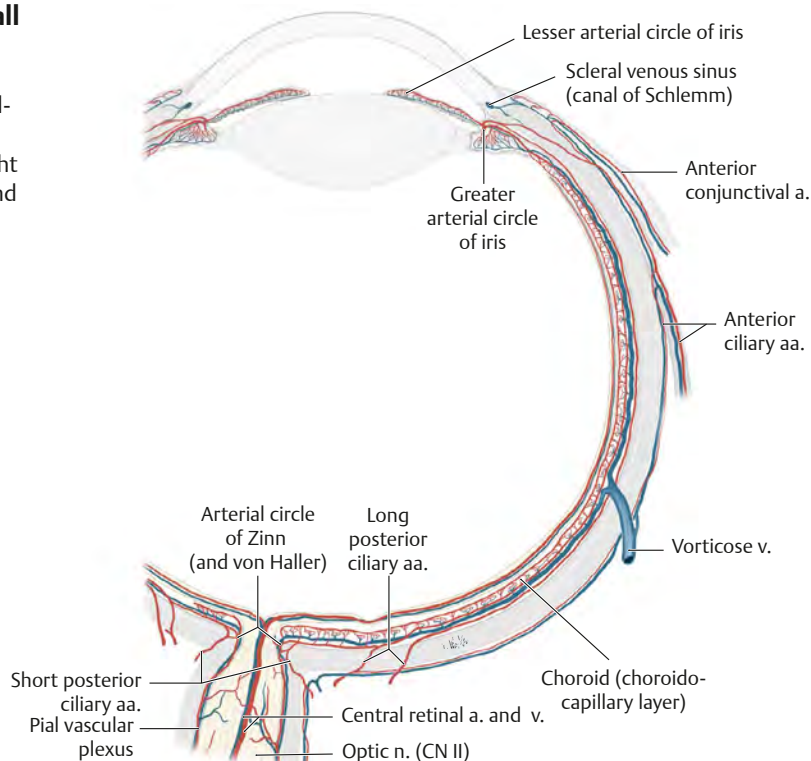
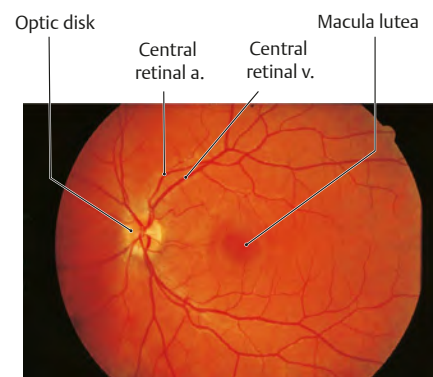
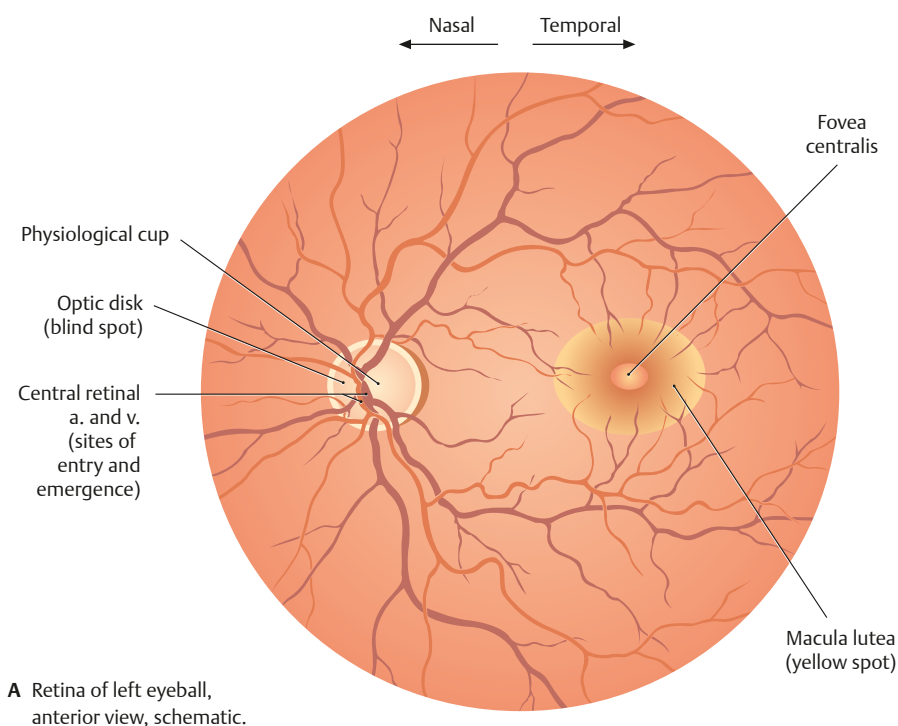


Fig. 42.16 Blood vessels of the eyeball

Transverse section through the right eyeball at the level of the optic nerve, superior view. The arteries of the eye arise from the ophthalmic artery, a terminal branch of the internal carotid artery. Blood is drained by four to eight vorticoses veins that open into the superior and inferior ophthalmic veins.

**Clinical box 42.4****Optic fundus**

The optic fundus is the only place in the body where capillaries can be examined directly. Examination of the optic fundus permits observation of vascular changes that may be caused by high blood pressure or diabetes. Examination of the optic disk is important in determining intracranial pressure and diagnosing multiple sclerosis.



B Normal optic fundus in the ophthalmoscopic examination.



C High intracranial pressure; the edges of the optic disk appear less sharp.

Cornea, Iris & Lens

Fig. 42.17 Cornea, iris, and lens

Transverse section through the anterior segment of the eye. Anterosuperior view.

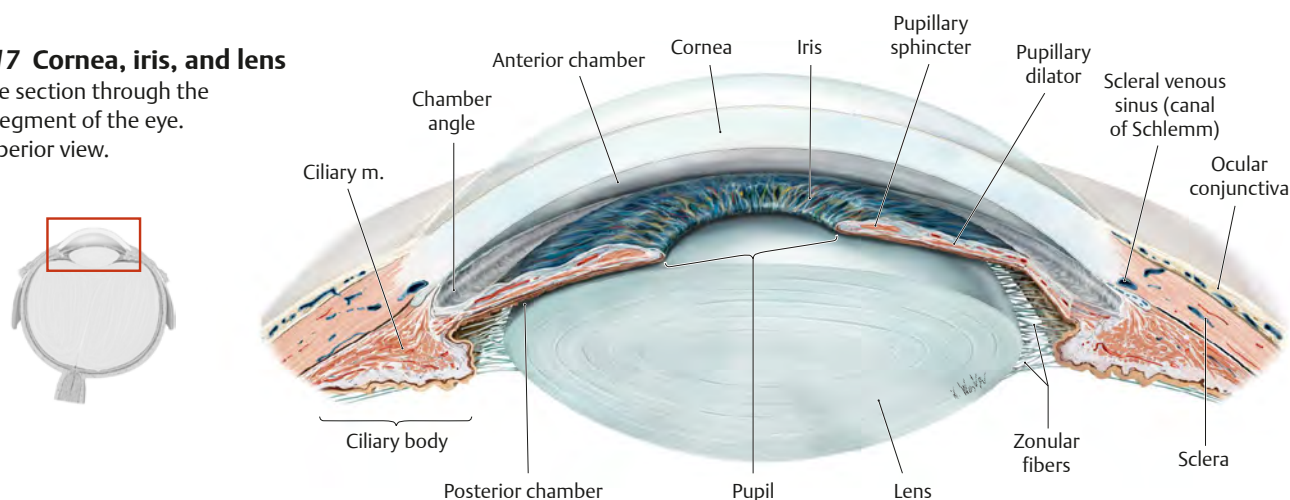
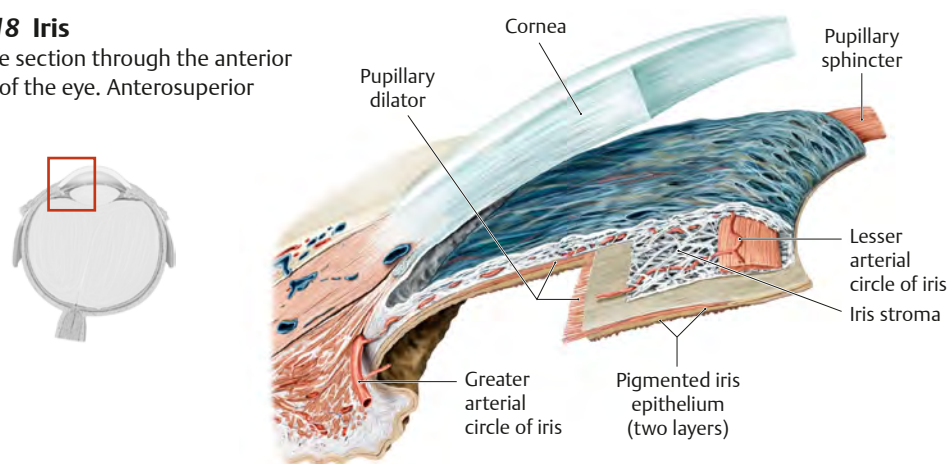


Fig. 42.18 Iris

Transverse section through the anterior segment of the eye. Anterosuperior view.

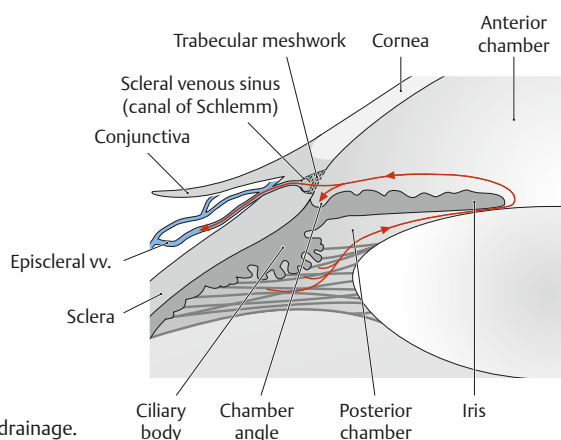


Clinical box 42.5

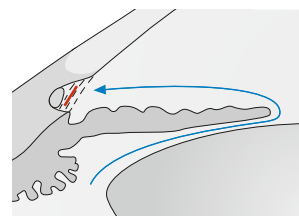
Glaucoma

Aqueous humor produced in the posterior chamber passes through the pupil into the anterior chamber. It seeps through the spaces of the trabecular meshwork into the scleral venous sinus (canal of Schlemm) before passing into the episcleral veins. Obstruction of aqueous humor drainage causes an increase in intraocular pressure (glaucoma), which constricts the optic nerve

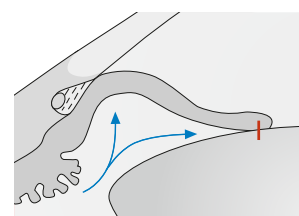
in the lamina cribrosa. This constriction eventually leads to blindness. The most common glaucoma (approximately 90% of cases) is chronic (open-angle) glaucoma. The more rare acute glaucoma is characterized by red eye, strong headache and/or eye pain, nausea, dilated episcleral veins, and edema of the cornea.



A Normal drainage.



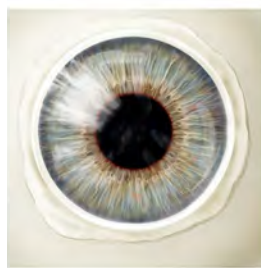
B Chronic (open-angle) glaucoma. Drainage through the trabecular meshwork is impaired.



C Acute (angle-closure) glaucoma. The chamber angle is obstructed by iris tissue. Aqueous fluid cannot drain into the anterior chamber, which pushes portions of the iris upward, blocking the chamber angle.

Fig. 42.19 Pupil

Pupil size is regulated by two intraocular muscles of the iris: the pupillary sphincter, which narrows the pupil (parasympathetic innervation), and the pupillary dilator, which enlarges it (sympathetic innervation).



A Normal pupil size.



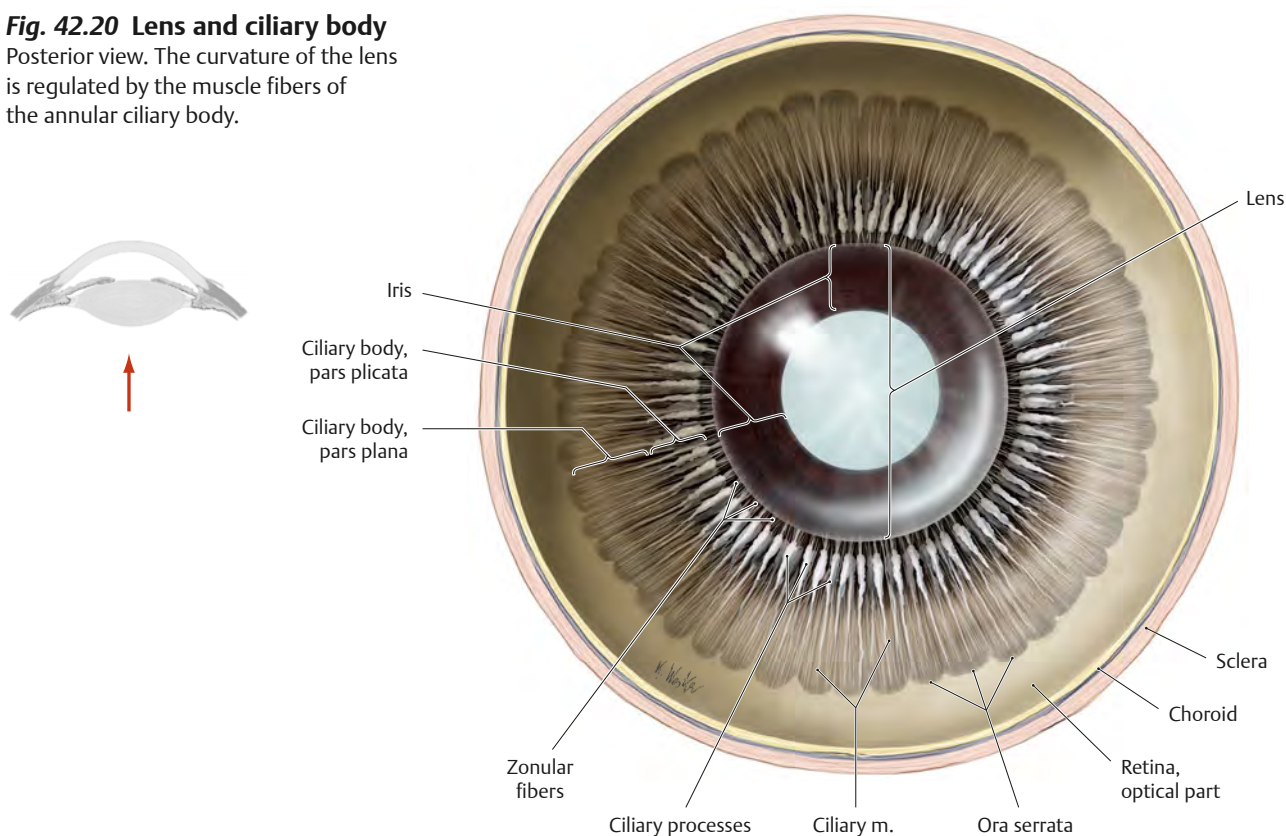
B Maximum constriction (miosis).



C Maximum dilation (mydriasis).

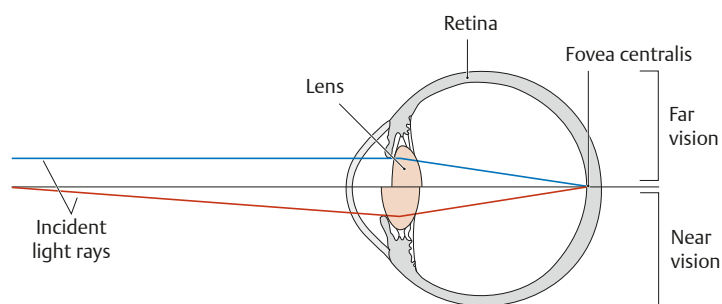
Fig. 42.20 Lens and ciliary body

Posterior view. The curvature of the lens is regulated by the muscle fibers of the annular ciliary body.

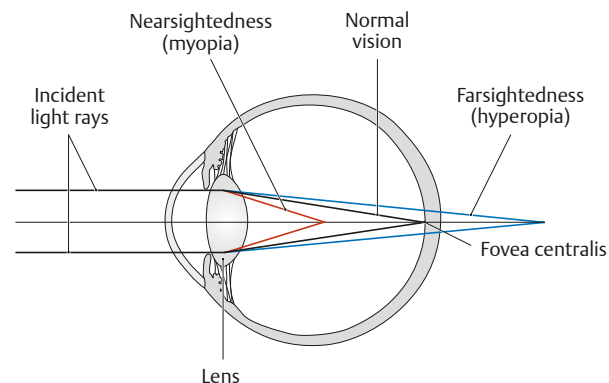
**Fig. 42.21 Light refraction by the lens**

Transverse section, superior view. In the normal (emmetropic) eye, light rays are refracted by the lens (and cornea) to a focal point on the retinal surface (fovea centralis). Tensing of the zonular fibers, with ciliary muscle relaxation, flattens the lens in response to parallel rays arriving

from a distant source (far vision). Contraction of the ciliary muscle, with zonular fiber relaxation, causes the lens to assume a more rounded shape (near vision).



A Normal dynamics of the lens.



B Abnormal lens dynamics.

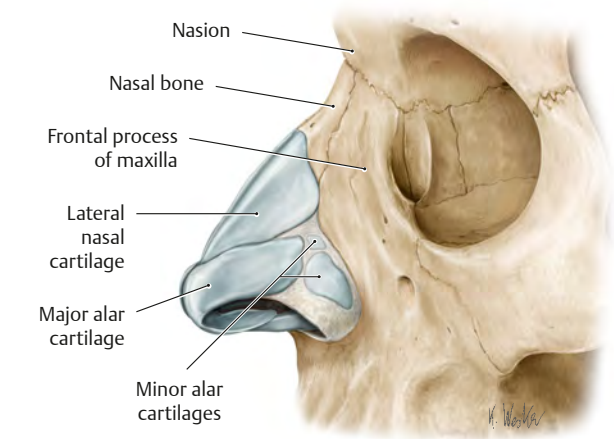
43 Nasal Cavity & Nose

Bones of the Nasal Cavity

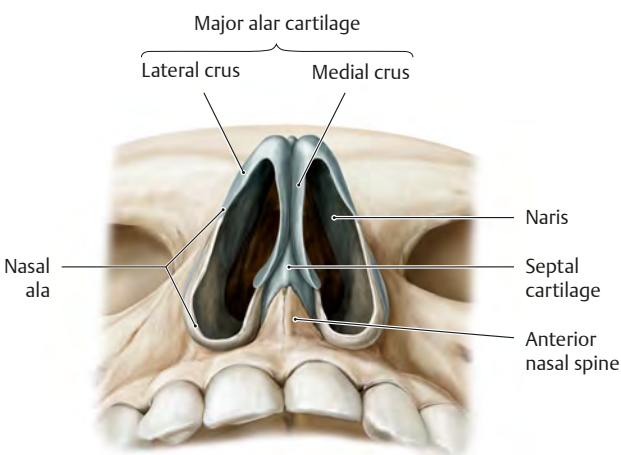
Fig. 43.1 Skeleton of the nose

The skeleton of the nose is composed of an upper bony portion and a lower cartilaginous portion. The proximal portions of the nostrils (alae)

are composed of connective tissue with small embedded pieces of cartilage.



A Left lateral view.

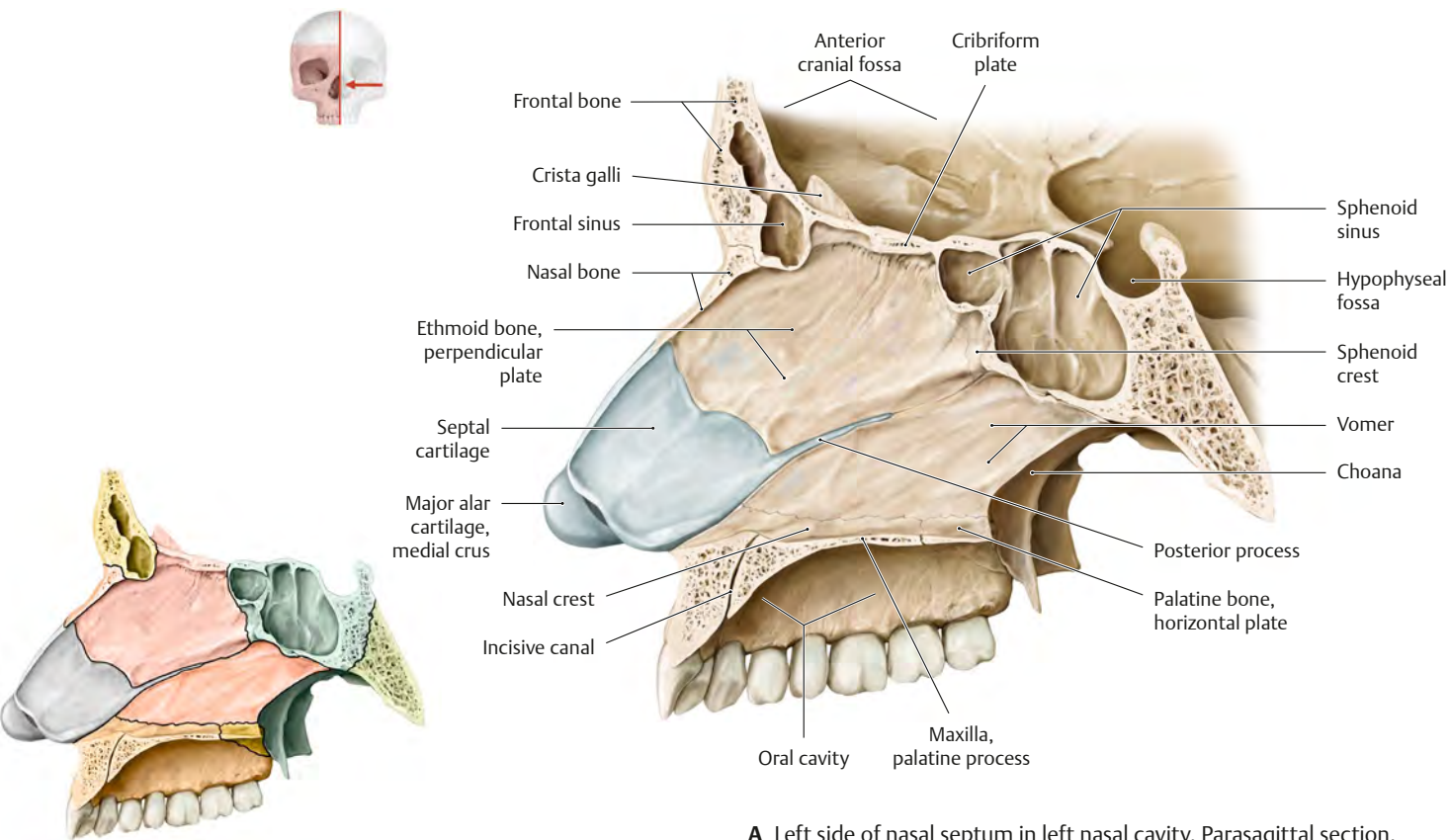


B Inferior view.

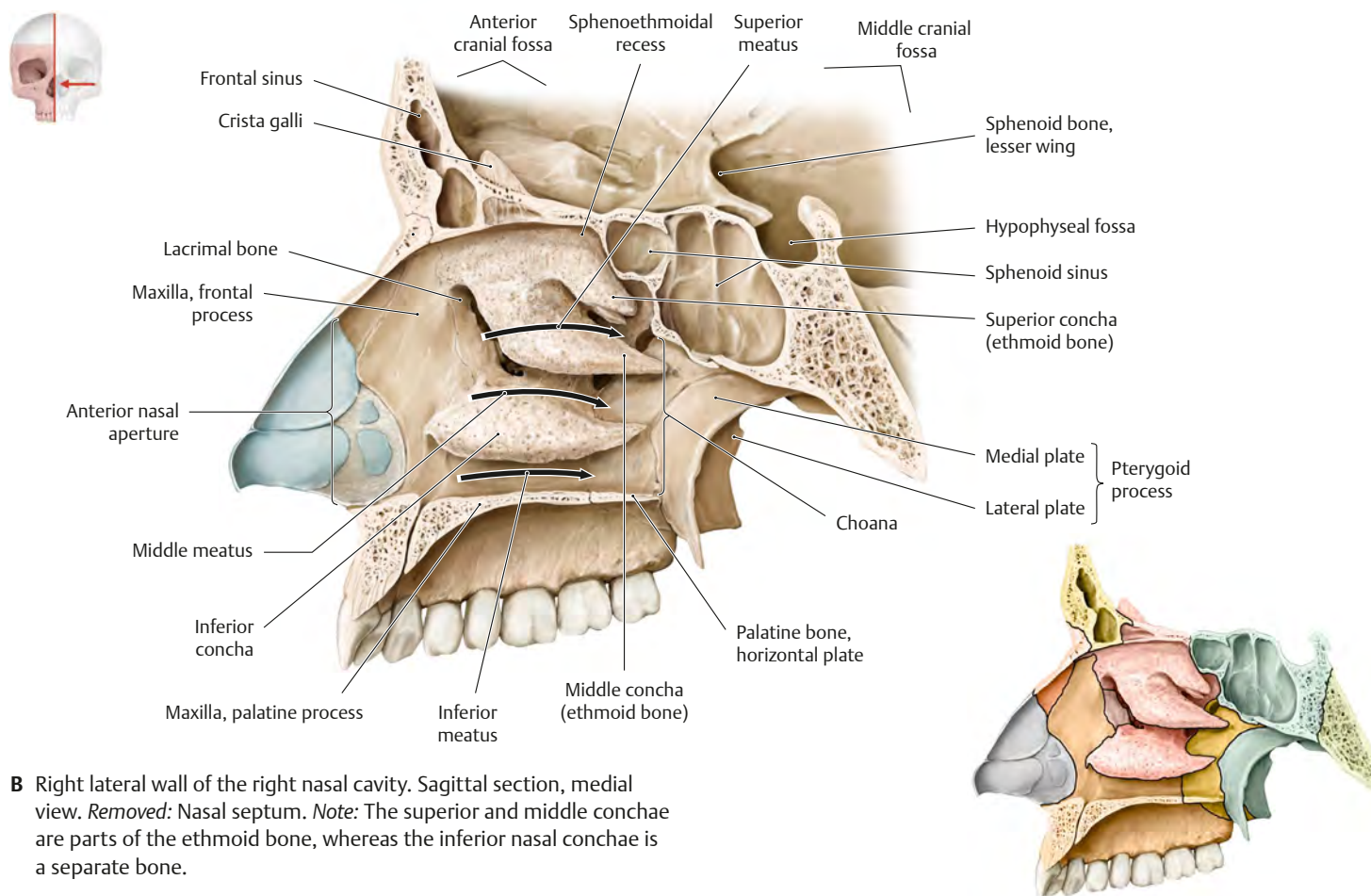
Fig. 43.2 Bones of the nasal cavity

The left and right nasal cavities are flanked by lateral walls and separated by the nasal septum. Air enters the nasal cavity through the anterior nasal aperture and travels through three passages: the

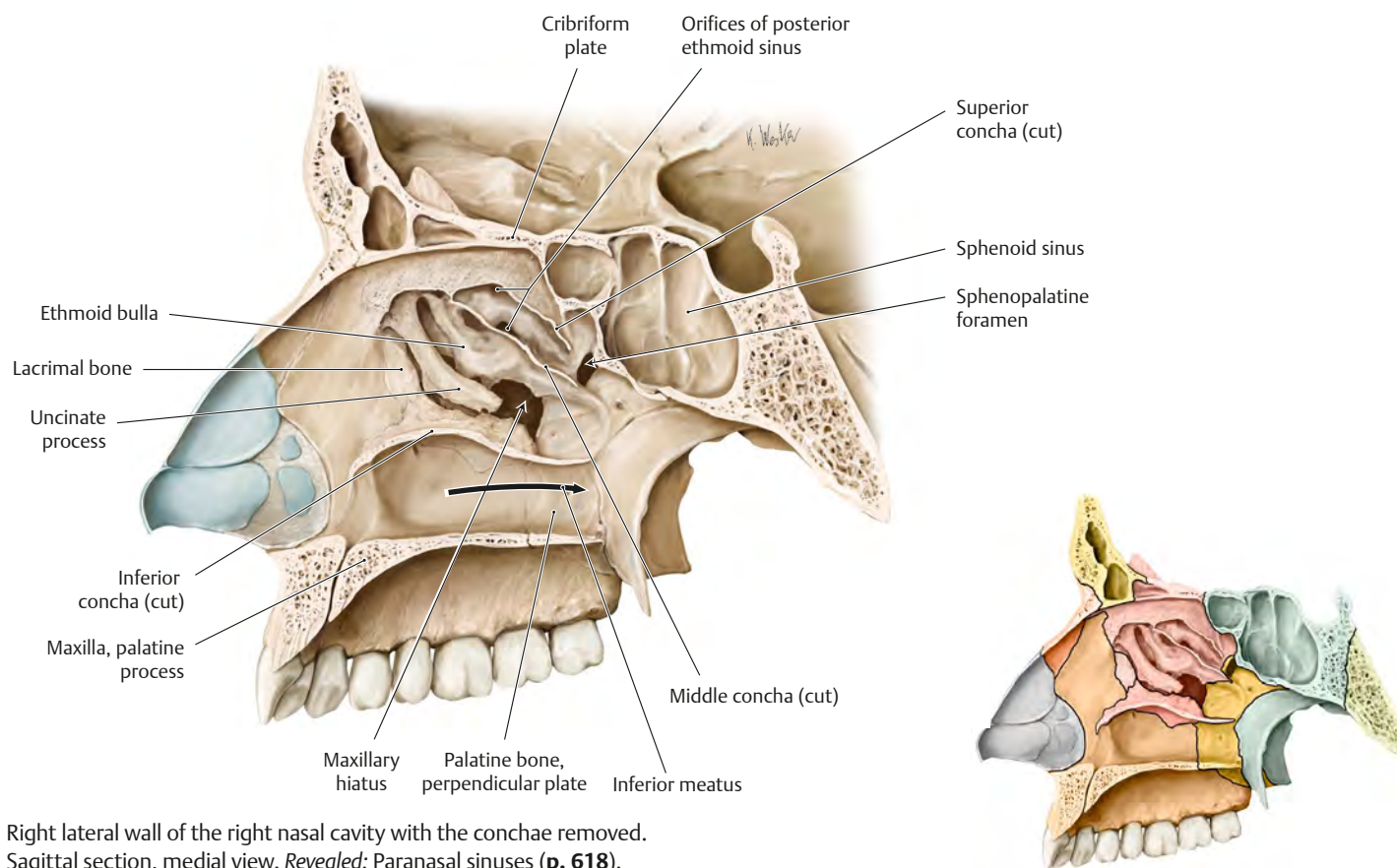
superior, middle, and inferior meatuses (*arrows*). These passages are separated by the superior, middle, and inferior conchae. Air leaves the nose through the choanae, entering the nasopharynx.



A Left side of nasal septum in left nasal cavity. Parasagittal section.



B Right lateral wall of the right nasal cavity. Sagittal section, medial view. *Removed:* Nasal septum. *Note:* The superior and middle conchae are parts of the ethmoid bone, whereas the inferior nasal conchae is a separate bone.

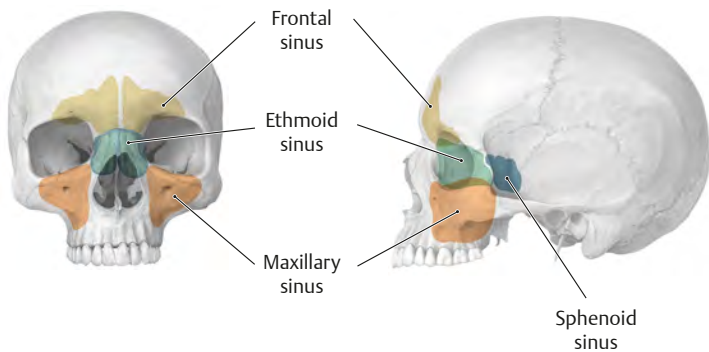


C Right lateral wall of the right nasal cavity with the conchae removed. Sagittal section, medial view. *Revealed:* Paranasal sinuses (p. 618).

Paranasal Air Sinuses

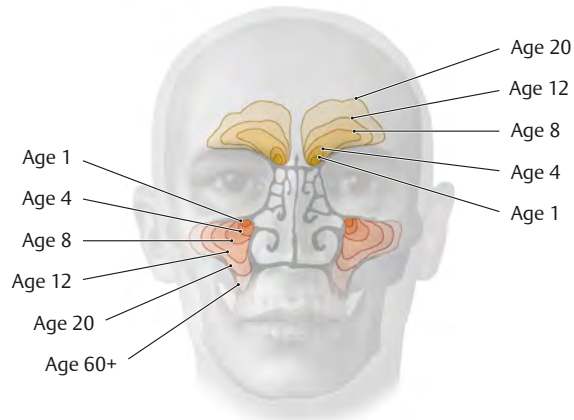
Fig. 43.3 Location of the paranasal sinuses

The paranasal sinuses (frontal, ethmoid, maxillary, and sphenoid) are air-filled cavities that reduce the weight of the skull.



A Anterior view.

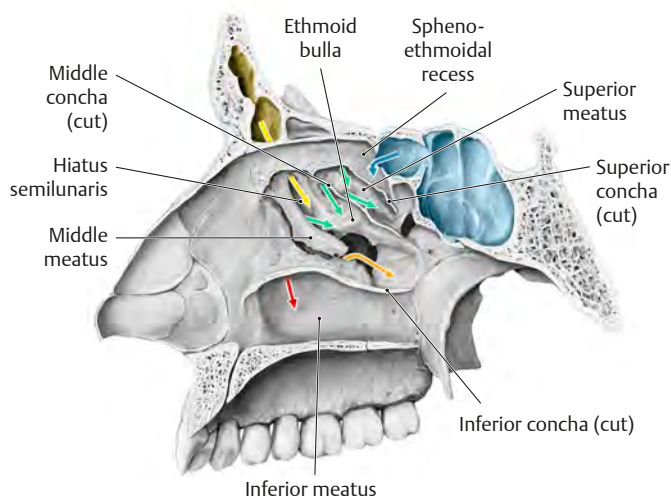
B Left lateral view.



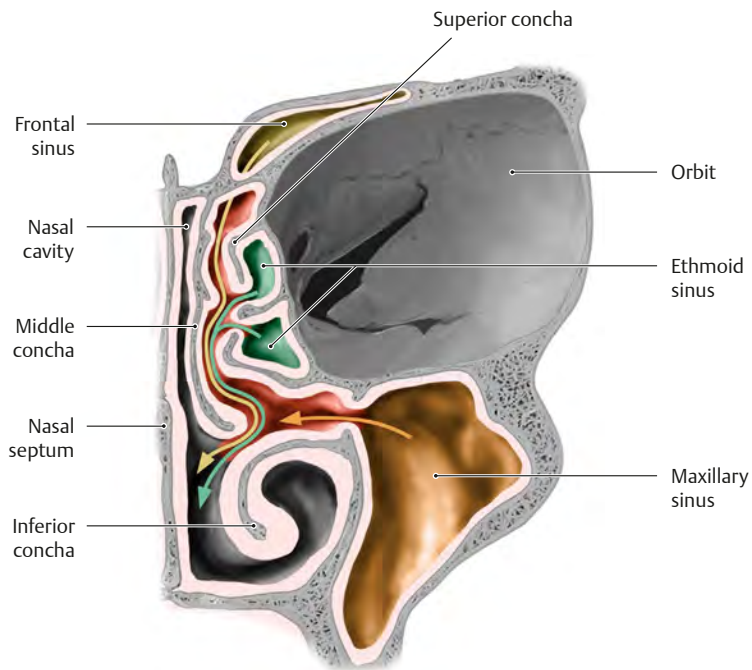
C Pneumatization (the formation of air-filled cells and cavities) of the sinuses with age. The frontal (yellow) and maxillary (orange) sinuses develop gradually over the course of cranial growth.

Fig. 43.4 Paranasal sinuses

Arrows indicate the flow of mucosal secretions from the sinuses and the nasolacrimal duct into the nasal cavity (see **Table 43.1**).



A Openings of the paranasal sinuses and nasolacrimal duct. Sagittal section, medial view of the right nasal cavity.



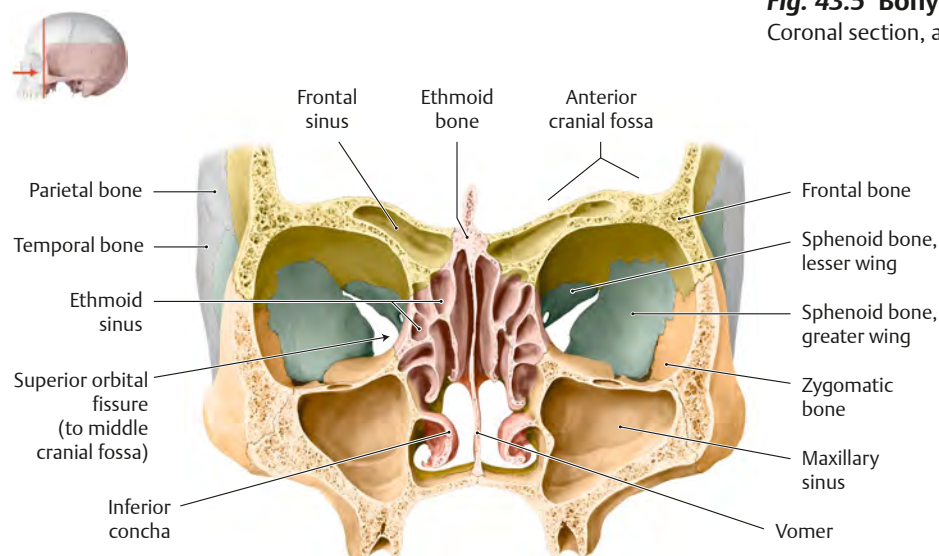
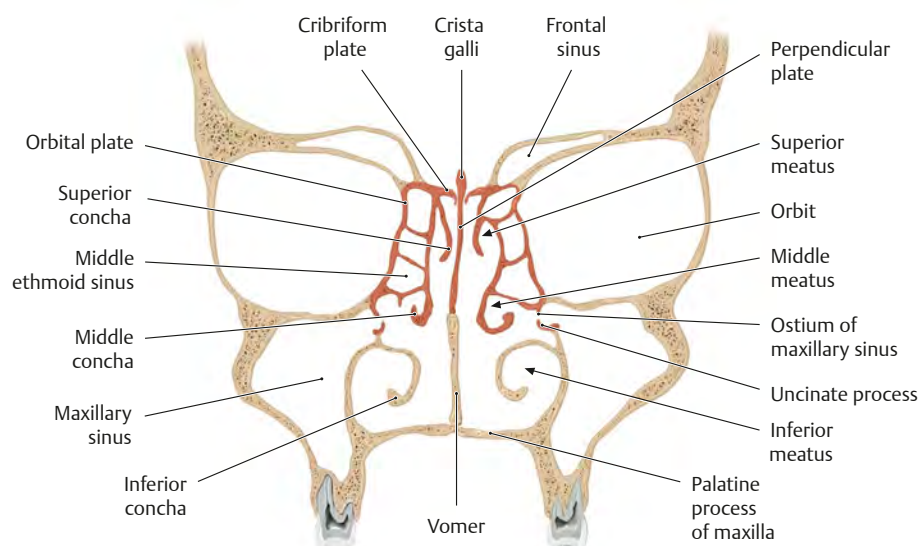
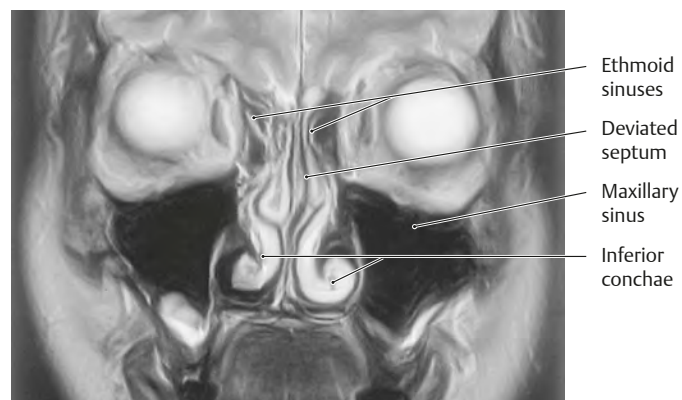
B Paranasal sinuses and osteomeatal unit in the left nasal cavity. Coronal section, anterior view.

Table 43.1 Nasal passages into which sinuses empty

Sinuses/duct		Nasal passage	Via
Sphenoid sinus (blue)		Sphenoethmoidal recess	Direct
Ethmoid sinus (green)	Posterior cells	Superior meatus	Direct
	Anterior and middle cells	Middle meatus	Ethmoid bulla
Frontal sinus (yellow)		Middle meatus	Frontonasal duct into hiatus semilunaris
Maxillary sinus (orange)		Middle meatus	Hiatus semilunaris
Nasolacrimal duct (red)		Inferior meatus	Direct

Fig. 43.5 Bony structure of the paranasal sinuses

Coronal section, anterior view.

**A** Bones of the paranasal sinuses.**B** Ethmoid bone (red) in the paranasal sinuses.**C** MRI through the paranasal sinuses.**Clinical box 43.1****Deviated septum**

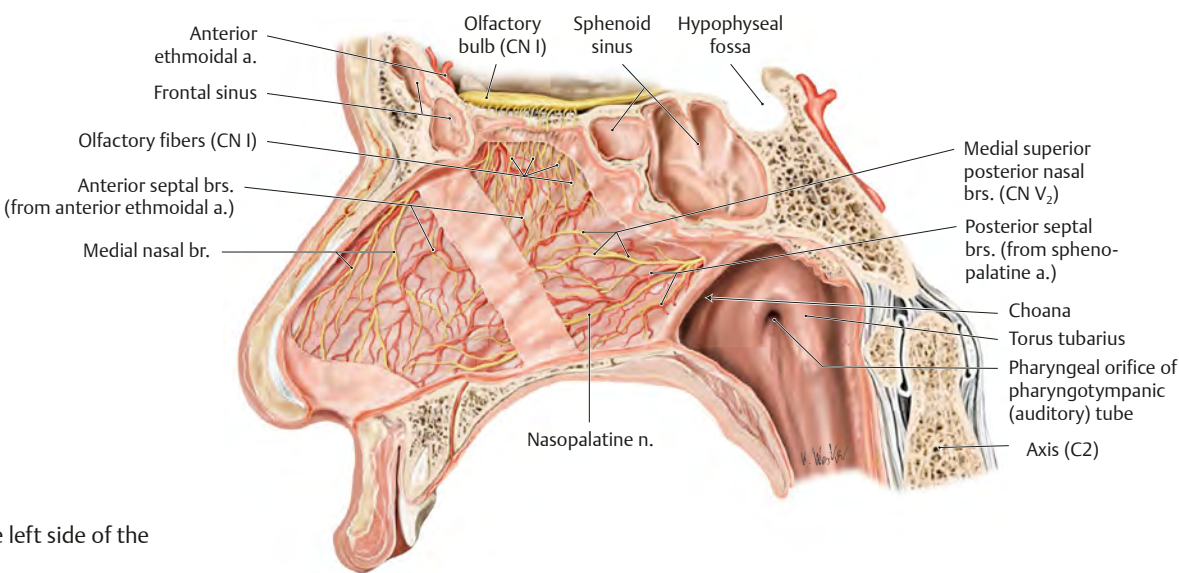
The normal position of the nasal septum creates two roughly symmetrical nasal cavities. Extreme lateral deviation of the septum may result in obstruction of the nasal passages. This may be corrected by removing portions of the cartilage (septoplasty).

Sinusitis

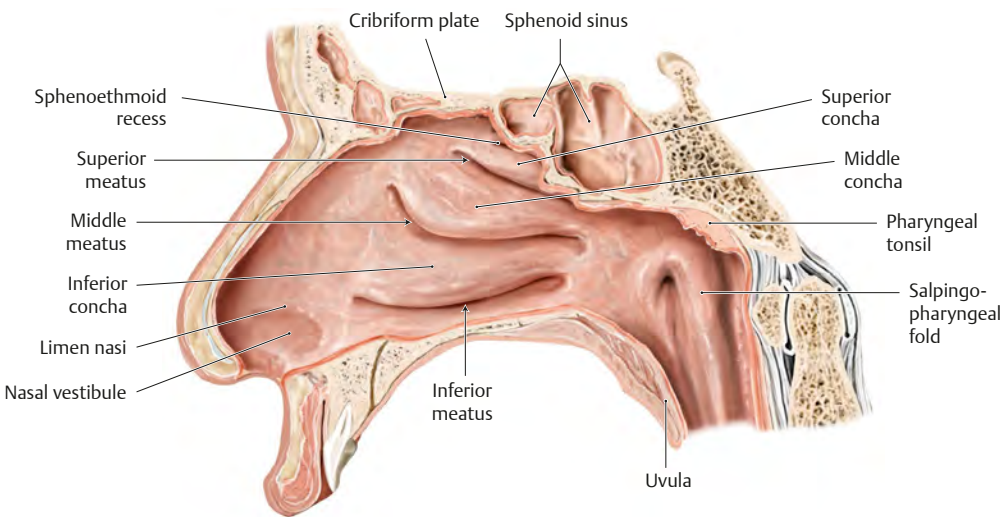
When the mucosa in the ethmoid sinuses becomes swollen due to inflammation (*sinusitis*), it blocks the flow of secretions from the frontal and maxillary sinuses in the osteomeatal unit (see **Fig. 43.4**). This may cause microorganisms to become trapped, causing secondary inflammations. In patients with chronic sinusitis, the narrow sites can be surgically widened to establish more effective drainage routes.

Neurovasculature of the Nasal Cavity

Fig. 43.6 Nasal septum and lateral wall



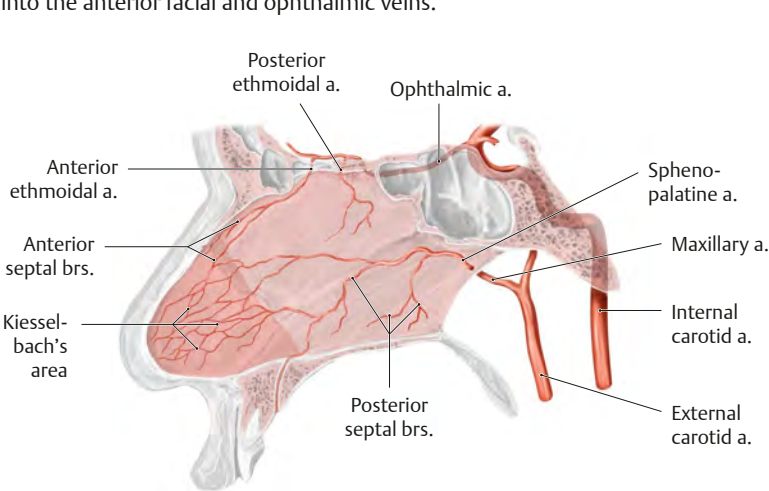
A Nerves and arteries of the left side of the nasal septum.



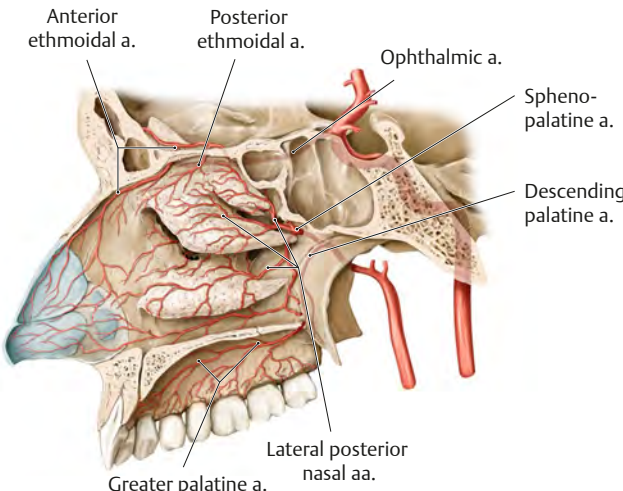
B Mucosa of the right lateral nasal wall. Sagittal section.

Fig. 43.7 Arteries of the nasal cavity

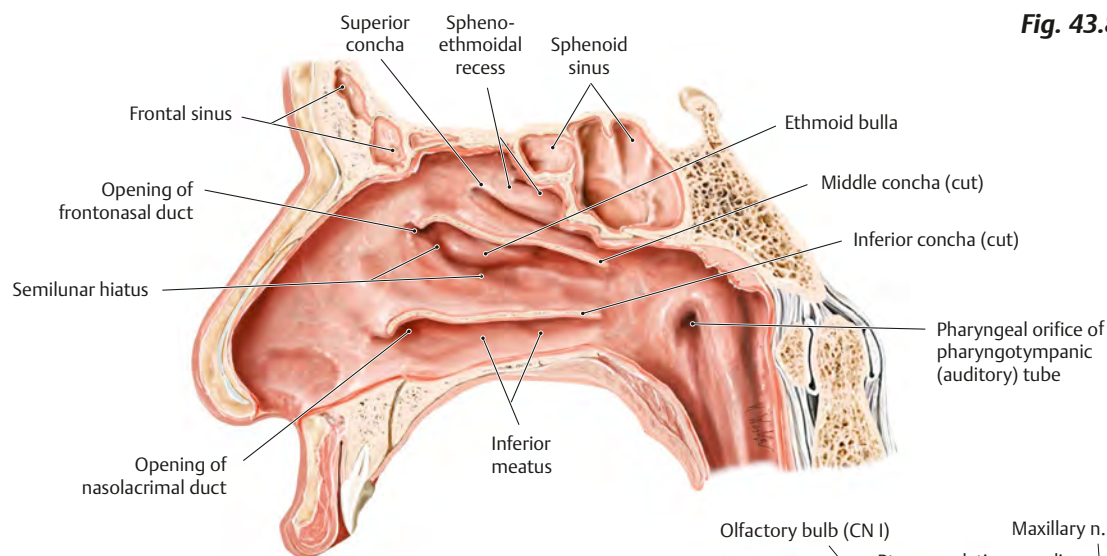
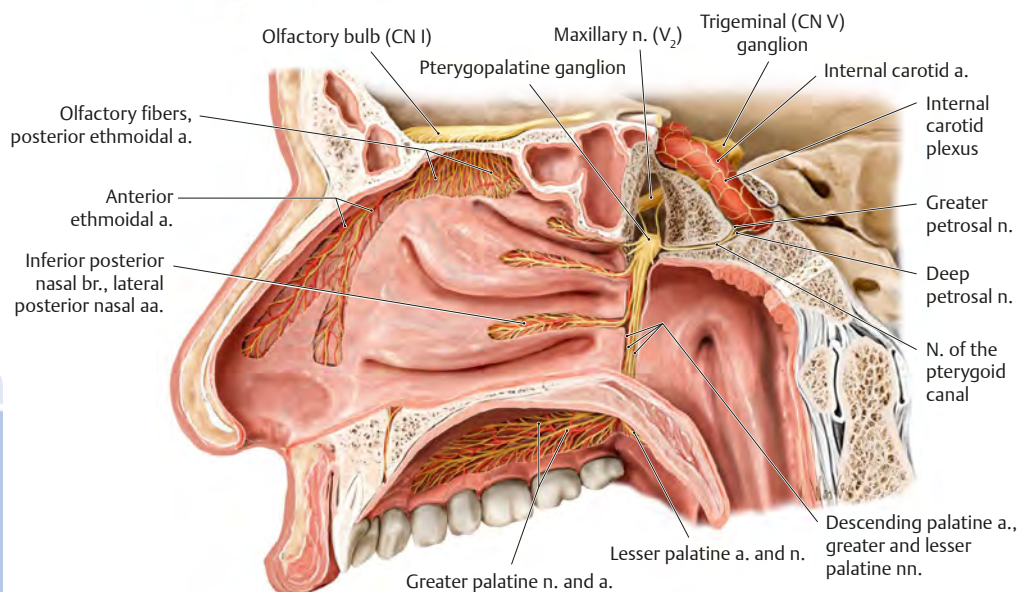
Note: The venous drainage of the nasal cavity is into the anterior facial and ophthalmic veins.



A Arteries of the left side of the nasal septum.



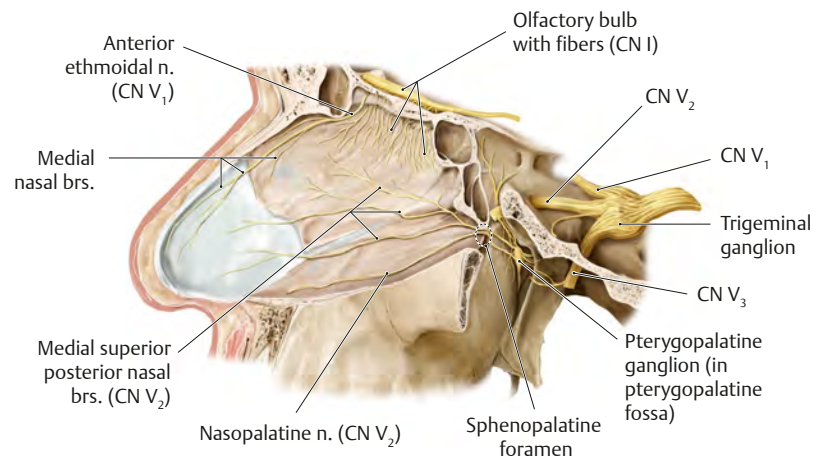
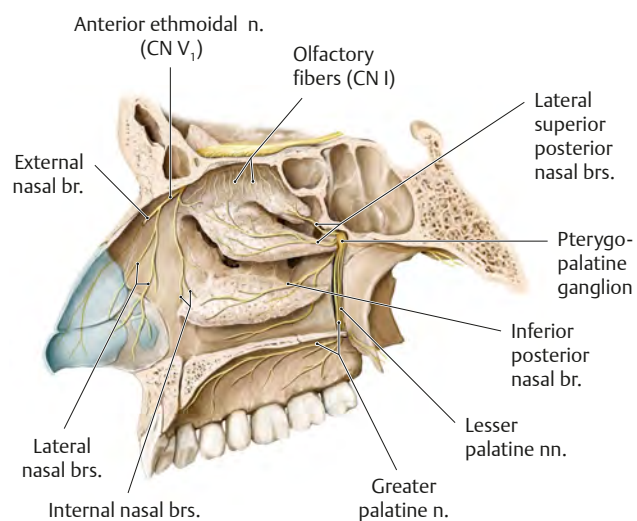
B Arteries of the right lateral nasal wall.

Fig. 43.8 Lateral nasal wall**A** Lateral nasal wall with middle and inferior conchae removed to show anatomy of underlying meatuses.**B** Nerves and arteries of the right lateral nasal wall. Sagittal section. *Removed:* Sphenopalatine foramen.**Clinical box 43.2****Nosebleeds**

Vascular supply to the nasal cavity arises from both the internal and external carotid arteries. The anterior part of the nasal septum contains a very vascularized region referred to as Kiesselbach's area. This area is the most common site of significant nosebleeds.

Fig. 43.9 Nerves of the nasal cavity

Left lateral view.

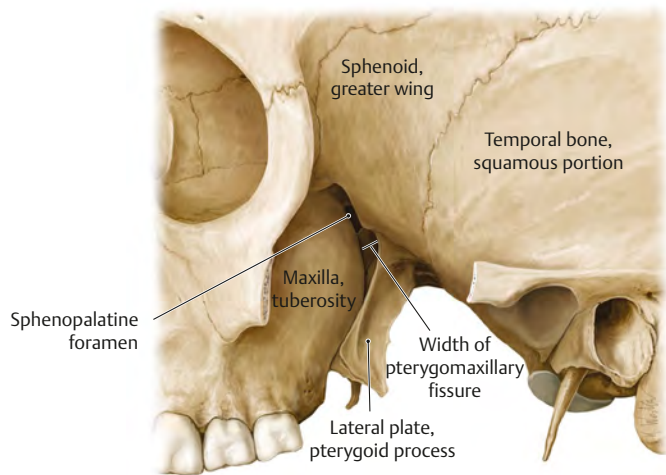
**A** Nerves of the left side of the nasal septum.**B** Nerves of the right lateral nasal wall.

Pterygopalatine Fossa

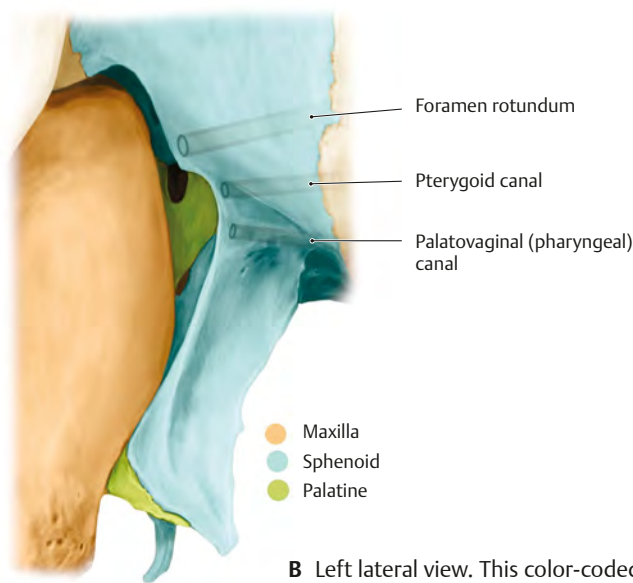
The pterygopalatine fossa is a small pyramidal space just inferior to the apex of the orbit. It is continuous with the infratemporal fossa laterally through the pterygomaxillary fissure. The pterygopalatine fossa is a

crossroad for neurovascular structures traveling between the middle cranial fossa, orbit, nasal cavity, and oral cavity.

Fig. 43.10 Bony boundaries of pterygopalatine fossa



A Left lateral view. The lateral approach through the infratemporal fossa via the pterygomaxillary fissure.



B Left lateral view. This color-coded version shows the location of the role of palatine bone.

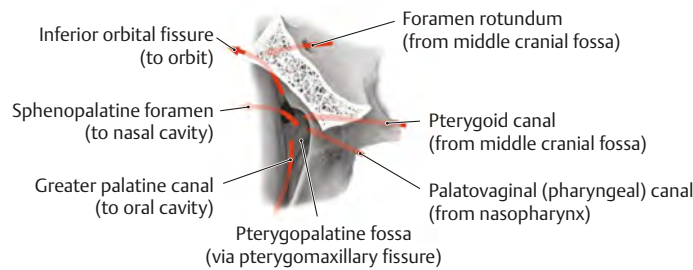


Table 43.2 Communications of the Pterygopalatine Fossa			
Communication	Direction	Via	Transmitted structures
Middle cranial fossa	Posterosuperiorly	Foramen rotundum	• Maxillary n. (CN V ₂)
Middle cranial fossa	Posteriorly in anterior wall of foramen lacerum	Pterygoid (vidian) canal	• N. of pterygoid canal, formed from: ◦ Greater petrosal n. (preganglionic parasympathetic fibers from CN VII) ◦ Deep petrosal n. (postganglionic sympathetic fibers from internal carotid plexus) • A. of pterygoid canal
Orbit	Anterosuperiorly	Inferior orbital fissure	• Vv. of pterygoid canal
Nasal cavity	Medially	Sphenopalatine foramen	• Branches of maxillary n. (CN V ₂) ◦ Infraorbital n. ◦ Zygomatic n. • Infraorbital a. and vv.
Oral cavity	Inferiorly	Greater palatine canal (foramen)	• Communicating vv. between inferior ophthalmic v. and pterygoid plexus of vv.
Nasopharynx	Inferoposteriorly	Palatovaginal (pharyngeal) canal	• Nasopalatine (sp) n. (CN V ₂), lateral and medial superior posterior nasal branches
Infratemporal fossa	Laterally	Pterygomaxillary fissure	• Sphenopalatine a. and vv.
			• Greater (descending) palatine n. (CN V ₂) and a.
			• Branches that emerge through lesser palatine canals: ◦ Lesser palatine nn. (CN V₂) and aa.
			• Pharyngeal branches of maxillary n. (CN V ₂), and pharyngeal a.
			• Maxillary a., pterygopalatine (third) part
			• Posterior superior alveolar n., a., and v.

The maxillary division of the trigeminal nerve (CN V₂, see **Fig. 40.9, p. 567**) passes from the middle cranial fossa through the foramen rotundum into the pterygopalatine fossa. The parasympathetic pterygopalatine ganglion receives postganglionic fibers from the greater petrosal nerve (the parasympathetic root of the nervus intermedius branch of the facial nerve). The preganglionic fibers of the pterygopala-

tine ganglion synapse with ganglion cells that innervate the lacrimal, small palatal, and small nasal glands. The sympathetic fibers of the deep petrosal nerve (sympathetic root) and sensory fibers of the maxillary nerve (sensory root) pass through the pterygopalatine ganglion without synapsing. The pterygopalatine structures can be seen from the medial view in **Fig. 43.8B, p. 621**.

Fig. 43.11 Nerves in the pterygopalatine fossa

Left lateral view. For simplicity in a small, structurally compressed area, numbers are used to identify the nerves. The key to these numbers is found in **Table 43.3** (below).

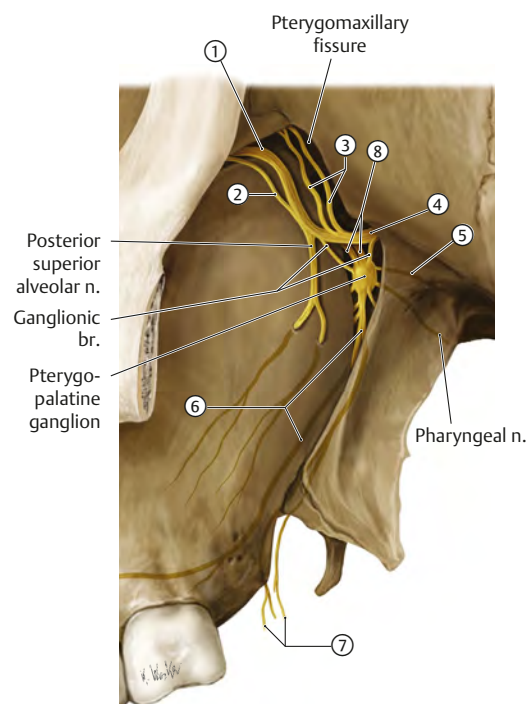


Fig. 43.12 Coronal view of the pterygopalatine fossa

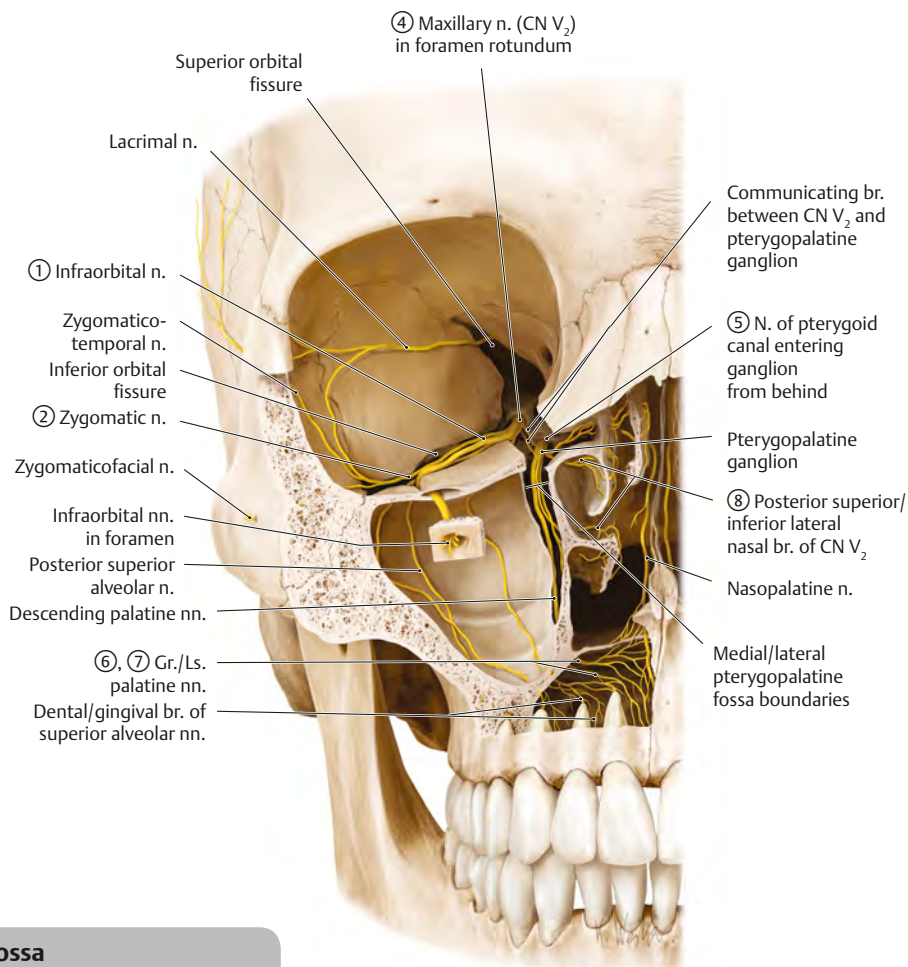


Table 43.3 Nerves of the pterygopalatine fossa

Origin of structures	Passageway	Transmitted nerves
Orbit	Inferior orbital fissure	① Infraorbital n.
		② Zygomatic n.
		③ Orbital brs. (from CN V ₂)
Middle cranial fossa	Foramen rotundum	④ Maxillary n. (CN V ₂)
Base of skull	Pterygoid (Vidian) canal	⑤ N. of pterygoid canal
Palate	Greater palatine canal	⑥ Greater palatine n.
	Lesser palatine canals	⑦ Lesser palatine nn.
Nasal cavity	Sphenopalatine foramen	⑧ Medial and lateral posterior superior and posterior inferior nasal brs. (from nasopalatine n., CN V ₂)

44 Temporal Bone & Ear

Temporal Bone

Fig. 44.1 Temporal bone

Left bone. The temporal bone consists of three major parts: squamous, petrous, and tympanic (see Fig. 44.2).

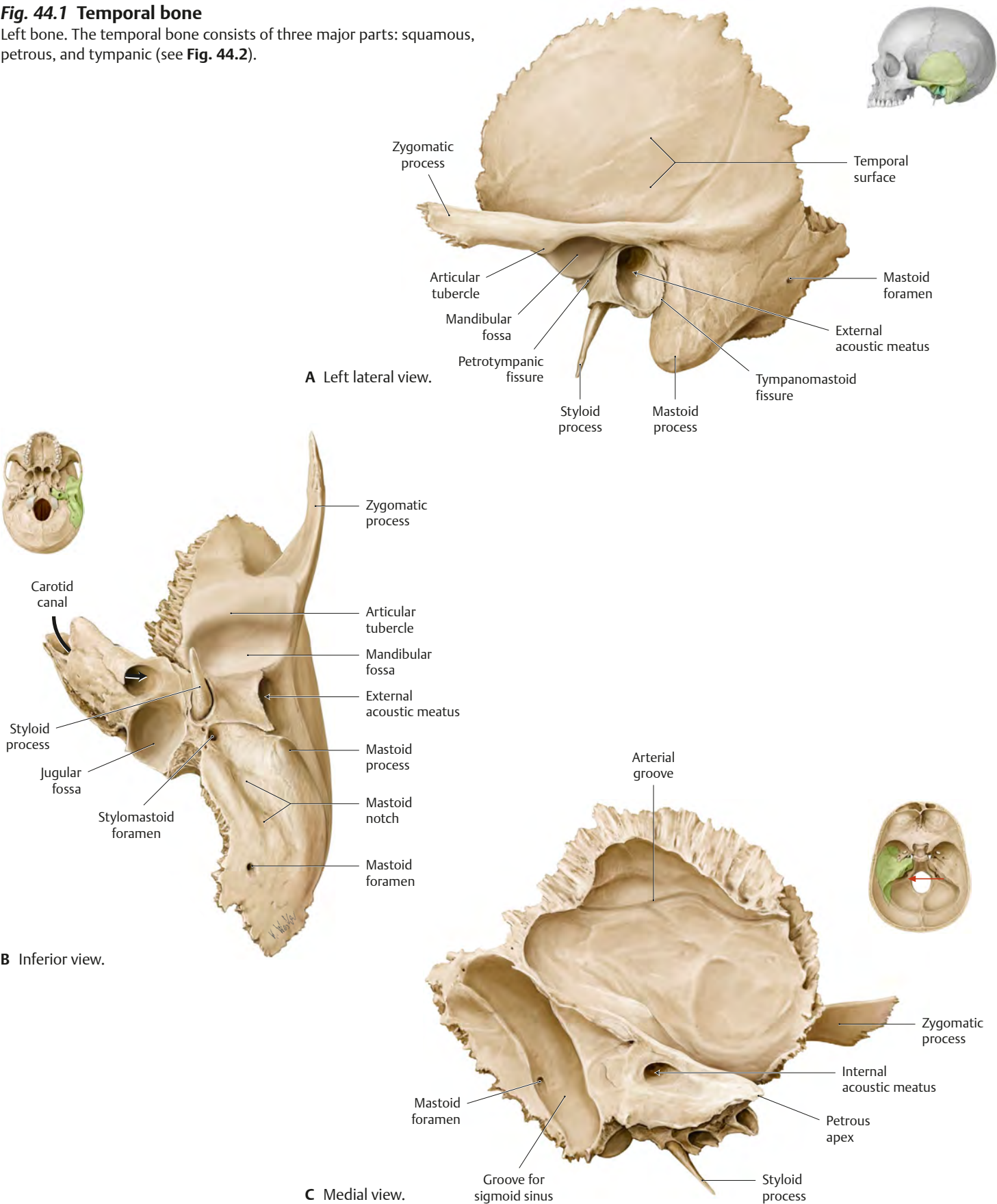
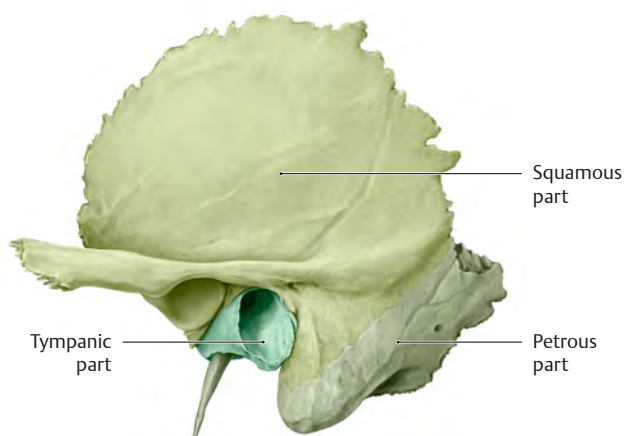
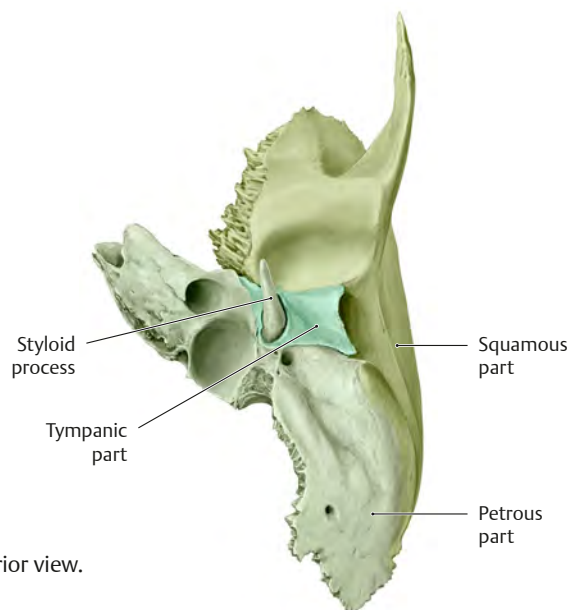


Fig. 44.2 Parts of the temporal bone



A Left lateral view.



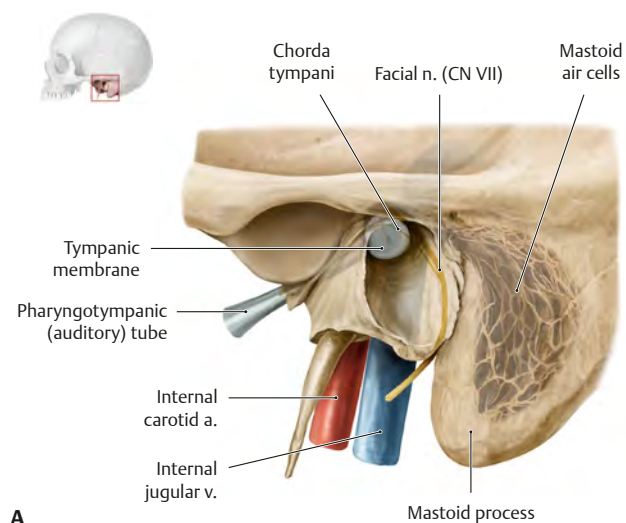
B Inferior view.



Clinical box 44.1

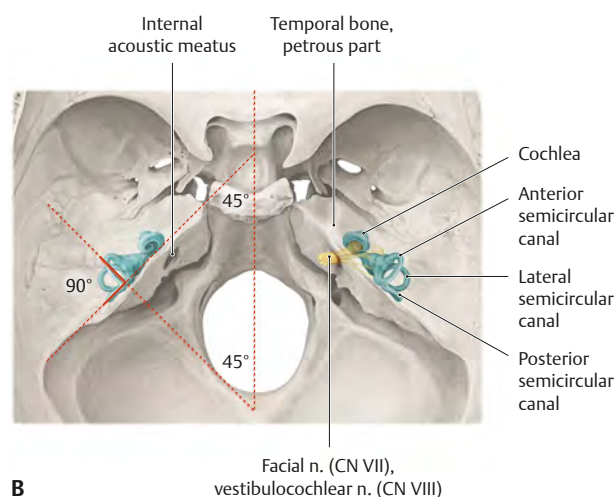
Structures in the temporal bone

The mastoid process contains mastoid air cells that communicate with the middle ear; the middle ear in turn communicates with the nasopharynx via the pharyngotympanic (auditory) tube (A). Bacteria may use this pathway to move from the nasopharynx into the middle ear. In severe cases, bacteria may pass from the mastoid air cells into the cranial cavity, causing meningitis.



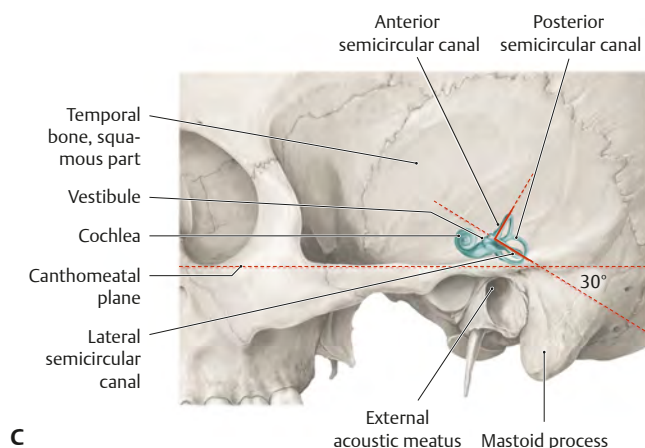
A

Irrigation of the auditory canal with warm (44°C) or cool (30°C) water can induce a thermal current in the endolymph of the semicircular canal, causing the patient to manifest vestibular nystagmus (jerky eye movements, vestibulo-ocular reflex). This caloric testing is important in the diagnosis of unexplained vertigo. The patient must be oriented so that the semicircular canal of interest lies in the vertical plane (C).



B

The petrous portion of the temporal bone contains the middle and inner ear as well as the tympanic membrane. The bony semicircular canals are oriented at an approximately 45-degree angle from the coronal, transverse, and sagittal planes (B).



C

External Ear & Auditory Canal

The auditory apparatus is divided into three main parts: external, middle, and inner ear. The external and middle ear are part of the sound conduction apparatus, and the inner ear is the actual organ of hearing

(see p. 634). The inner ear also contains the vestibular apparatus, the organ of balance (see p. 634).

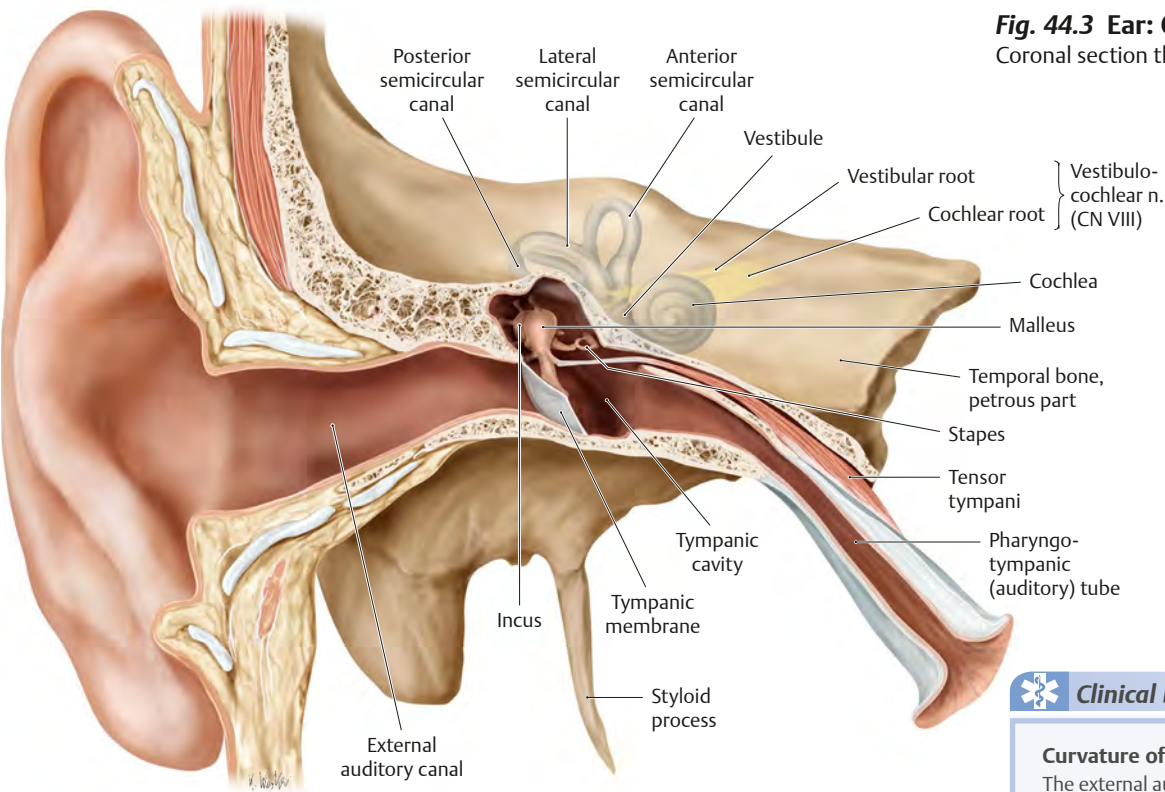
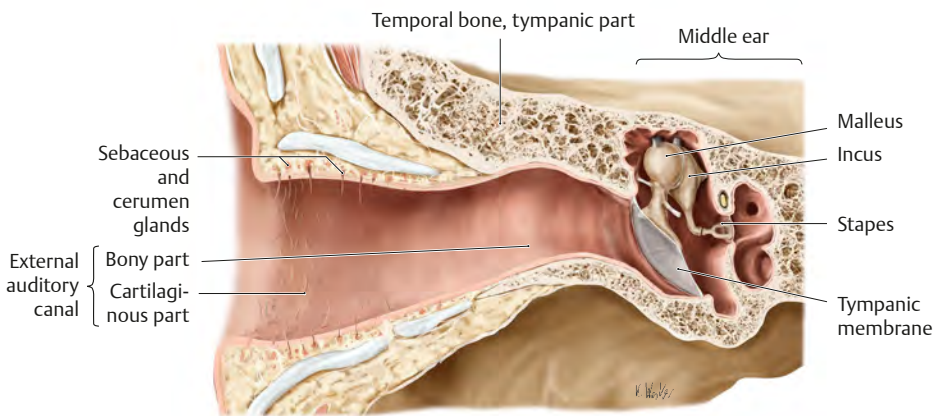


Fig. 44.3 Ear: Overview
Coronal section through right ear, anterior view.

Fig. 44.4 External auditory canal
Coronal section through right ear, anterior view. The tympanic membrane separates the external auditory canal from the tympanic cavity (middle ear). The outer third of the auditory canal is cartilaginous, and the inner two thirds are osseous (tympanic part of temporal bone).



Clinical box 44.2

Curvature of the external auditory canal

The external auditory canal is most curved in its cartilaginous portion. When an otoscope is being inserted, the auricle should be pulled backward and upward so the speculum can be introduced into a straightened canal.

A Insertion of otoscope.

B Anterior view.

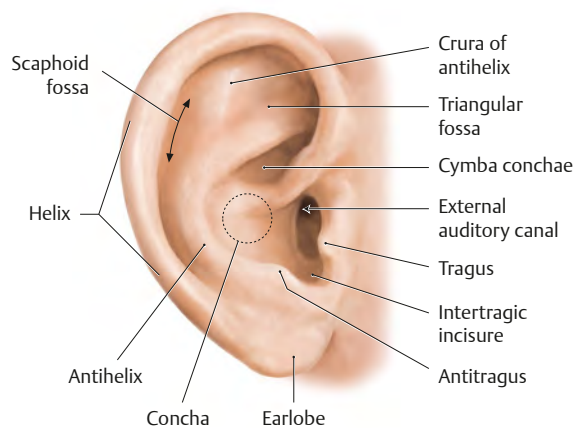
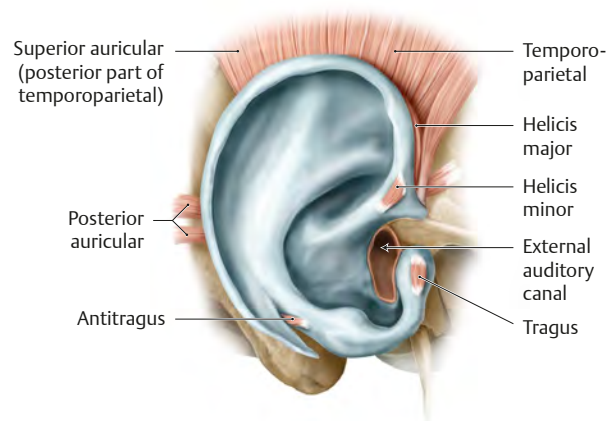
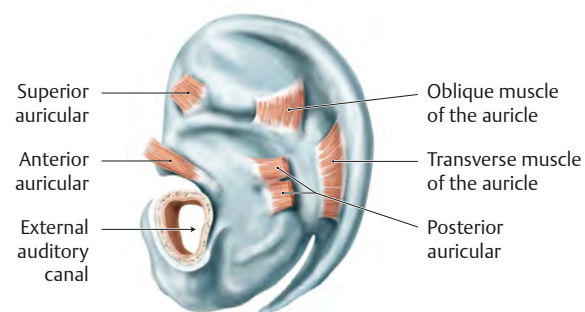
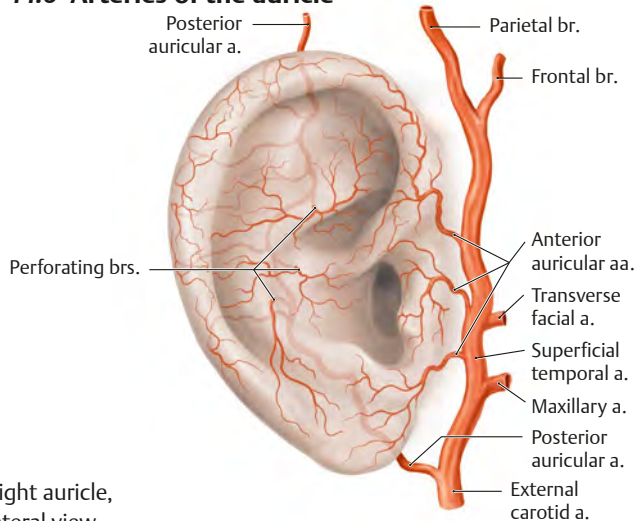
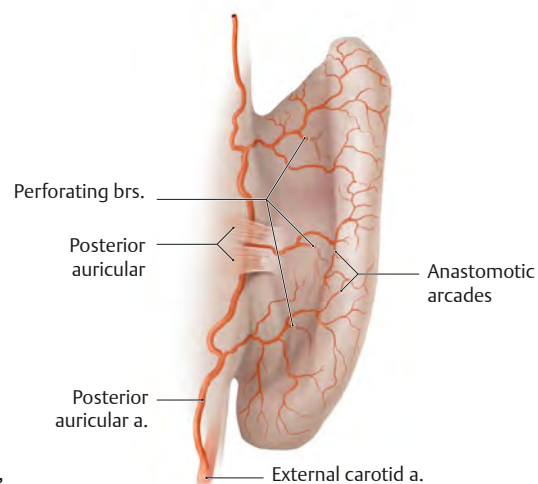
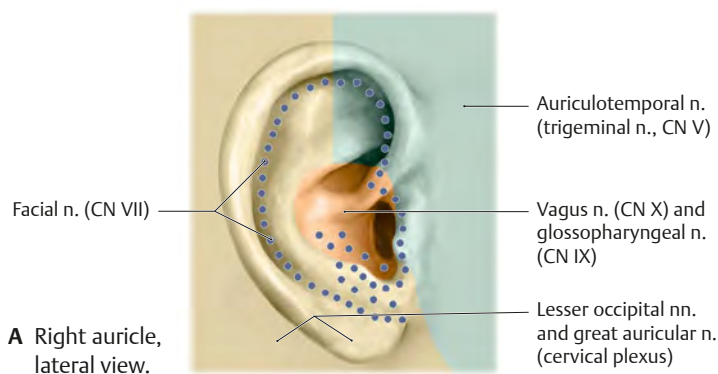
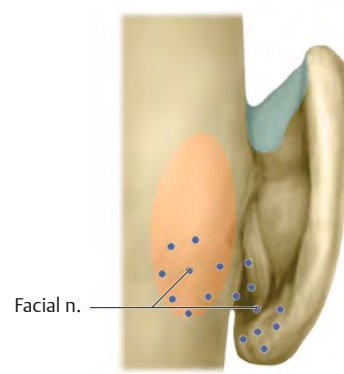
Tympanic membrane

C Transverse section.

Head of mandible

Fig. 44.5 Structure of the auricle

The auricle of the ear encloses a cartilaginous framework that forms a funnel-shaped receptor for acoustic vibrations. The muscles of the auricle are considered muscles of facial expression, although they are vestigial in humans.

**A** Right auricle, right lateral view.**B** Cartilage and muscles of the right auricle, right lateral view.**C** Cartilage and muscles of the right auricle, medial view of posterior surface.**Fig. 44.6 Arteries of the auricle****A** Right auricle, lateral view.**B** Right auricle, posterior view.**Fig. 44.7 Innervation of the auricle****A** Right auricle, lateral view.**B** Right auricle, posterior view.

Middle Ear: Tympanic Cavity

Fig. 44.8 Middle ear

Right petrous bone, superior view. The tympanic cavity of the middle ear communicates anteriorly with the pharynx via the pharyngotympanic (auditory) tube and posteriorly with the mastoid air cells.

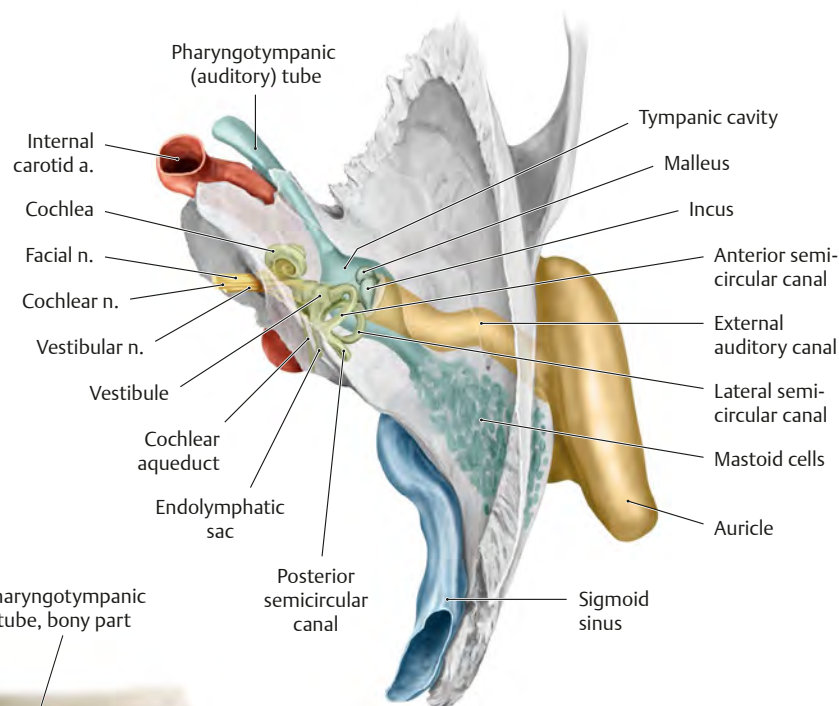


Fig. 44.9 Tympanic cavity and pharyngotympanic tube

Medial view of opened tympanic cavity.

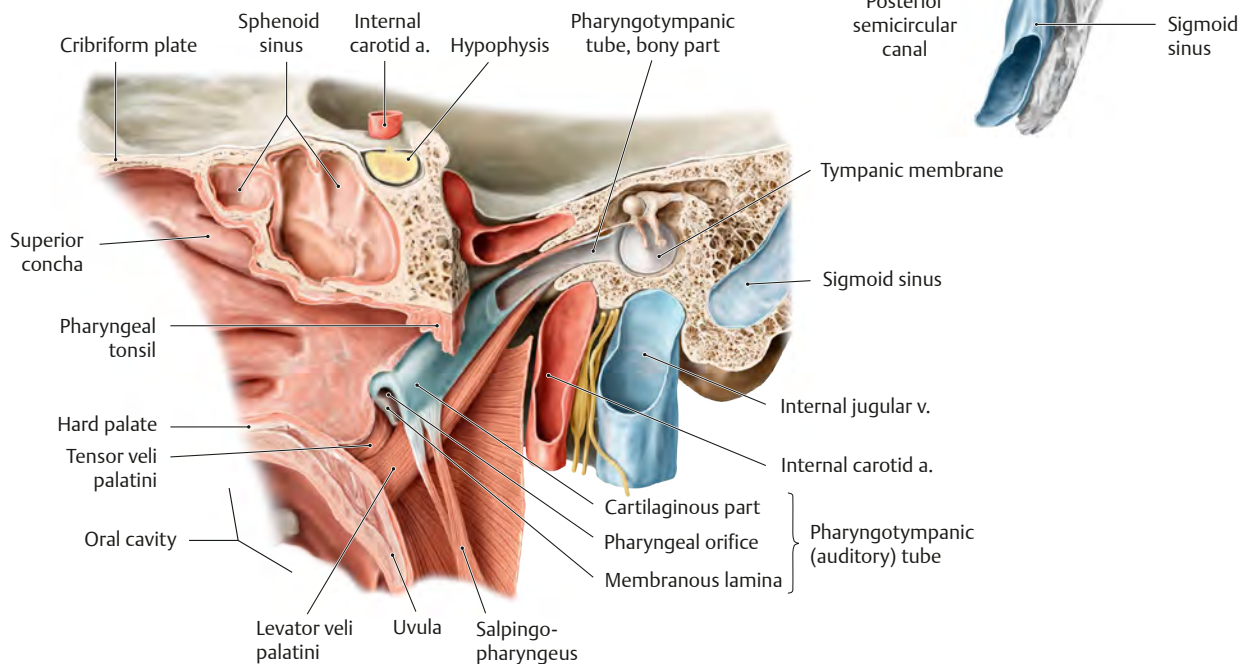


Table 44.1	Boundaries of the tympanic cavity			
During chronic suppurative otitis media (inflammation of the middle ear), pathogenic bacteria may spread to adjacent regions.				
Direction	Wall	Anatomical boundary	Neighboring structures	Infection
Anterior	Carotid	Opening to pharyngotympanic tube	Carotid canal	
Lateral	Membranous	Tympanic membrane	External ear	
Superior	Tegmental	Tegmen tympani	Middle cranial fossa	Meningitis, cerebral abscess (especially of temporal lobe)
Medial	Labyrinthine	Promontory overlying basal turn of cochlea	Inner ear	
			CSF space (via petrous apex)	Abducent paralysis, trigeminal nerve irritation, visual disturbances (Gradenigo's syndrome)
Inferior	Jugular	Temporal bone, tympanic part	Bulb of jugular v.	
			Sigmoid sinus	Sinus thrombosis
Posterior	Mastoid	Aditus to mastoid antrum	Air cells of mastoid process	Mastoiditis
			Facial n. canal	Facial paralysis
CSF, cerebrospinal fluid.				

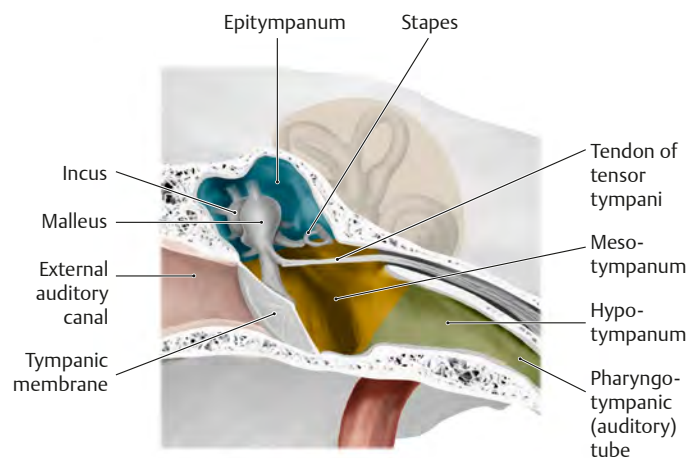
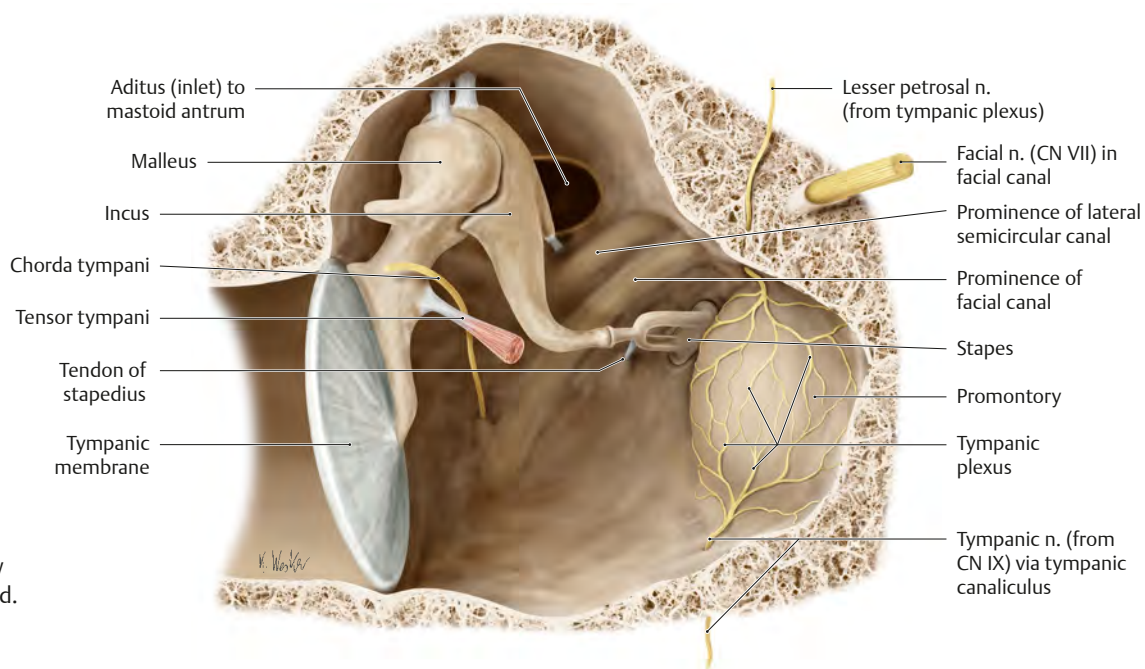
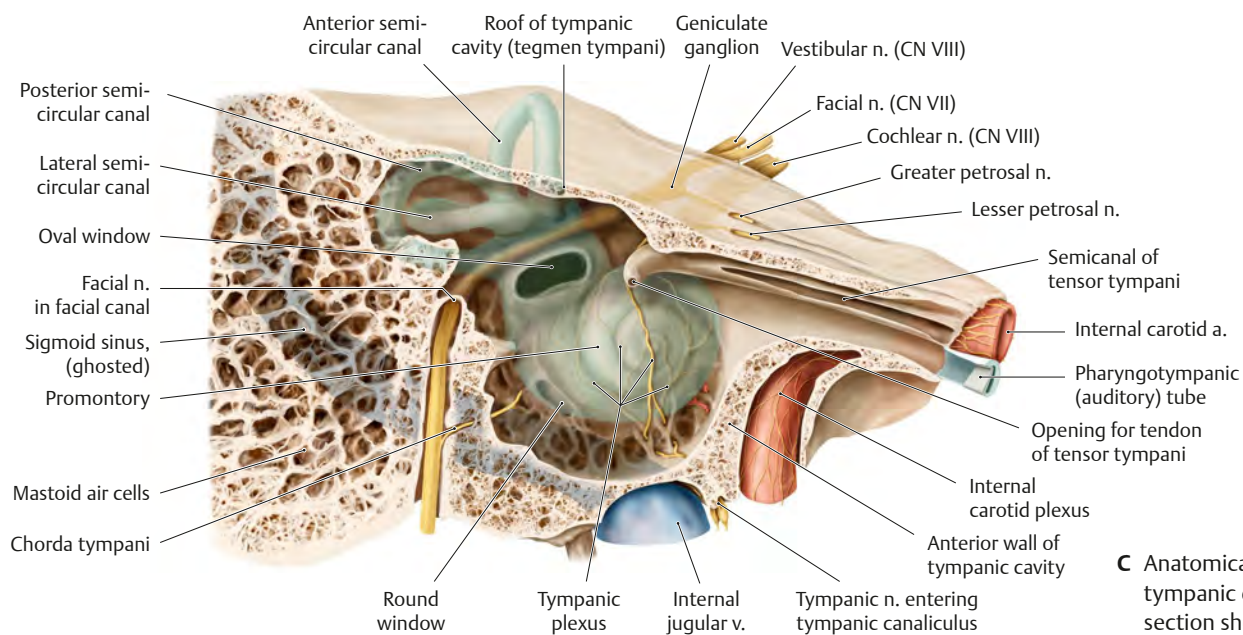


Fig. 44.10 Tympanic cavity

A Levels of the tympanic cavity. Anterior view. The tympanic cavity is divided into three levels: epi-, meso-, and hypotympanum.



B Coronal section, anterior view with the anterior wall removed.

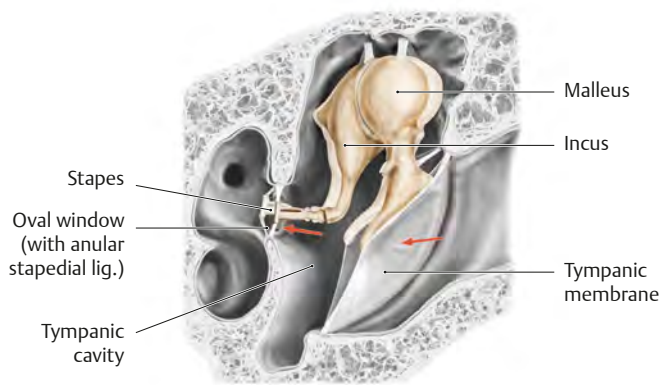


C Anatomical relationships of the tympanic cavity. Oblique sagittal section showing the medial wall.

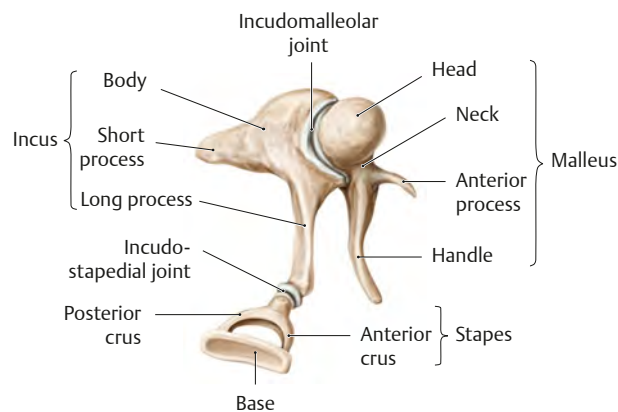
Middle Ear: Ossicular Chain & Tympanic Membrane

Fig. 44.11 Auditory ossicles

Left ear. The ossicular chain consists of three small bones that establish an articular connection between the tympanic membrane and the oval window.



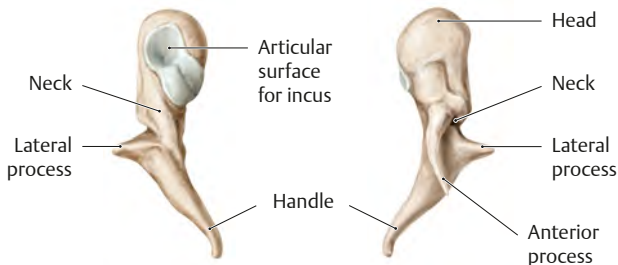
A Auditory ossicles in the middle ear. Anterior view.



B Bones of the ossicular chain. Medial view of the left ossicular chain.

Fig. 44.12 Malleus (“hammer”)

Left ear.

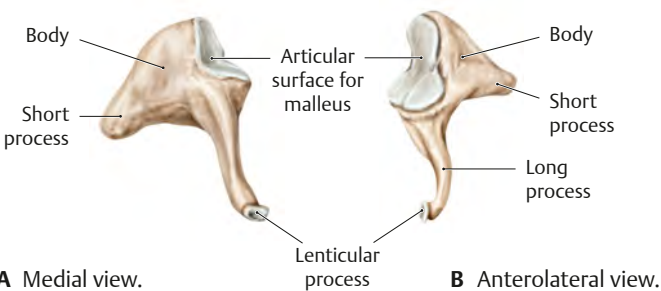


A Posterior view.

B Anterior view.

Fig. 44.13 Incus (“anvil”)

Left ear.

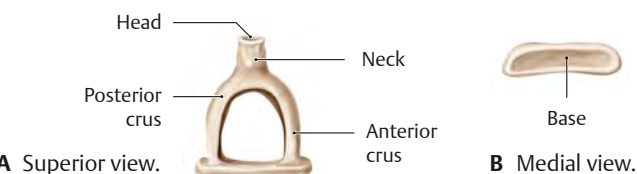


A Medial view.

B Anterolateral view.

Fig. 44.14 Stapes (“stirrup”)

Left ear.

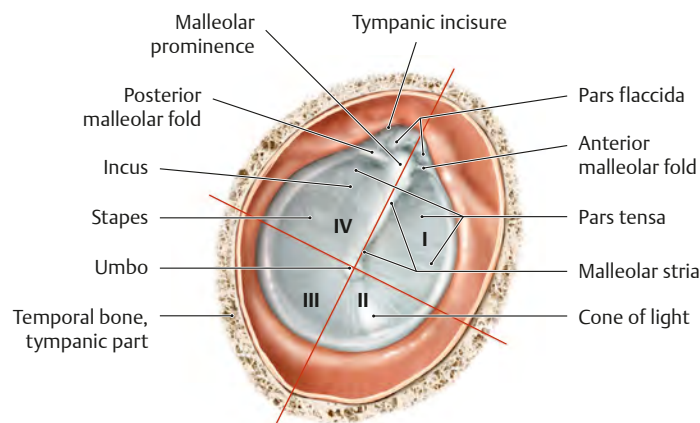


A Superior view.

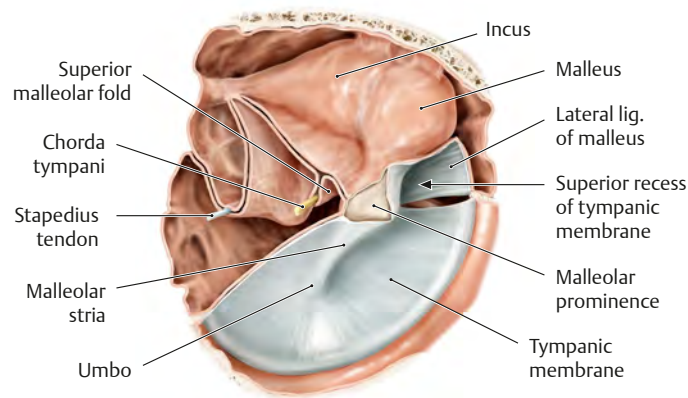
B Medial view.

Fig. 44.15 Tympanic membrane

Right tympanic membrane. The tympanic membrane is divided into four quadrants (I–IV).



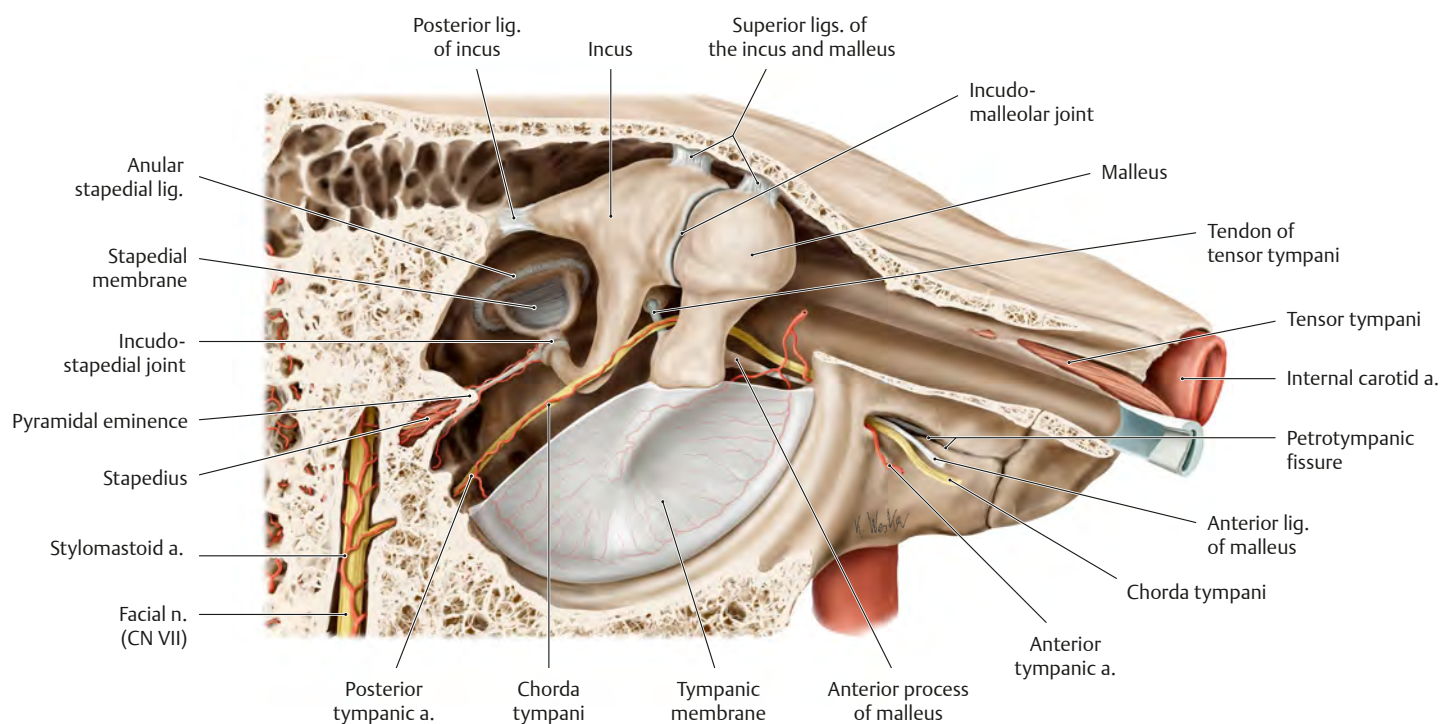
A Lateral view of the right tympanic membranewith quadrants indicated.



B Mucosal lining of the tympanic cavity. Posterolateral view with the tympanic membrane partially removed.

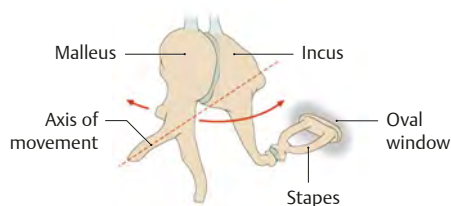
Fig. 44.16 Ossicular chain in the tympanic cavity

Lateral view of the right ear. *Revealed:* Ligaments of the ossicular chain and muscles of the middle ear (stapedius and tensor tympani).

**Clinical box 44.3****Ossicular chain in hearing**

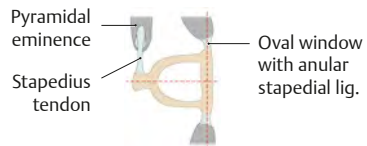
Sound waves funneled into the external auditory canal set the tympanic membrane into vibration. The ossicular chain transmits the vibrations to the oval window, which communicates them to the fluid column of the inner ear. Sound waves in fluid meet with higher impedance; they must therefore be amplified in the middle ear. The difference in surface area between the tympanic

membrane and the oval window increases the sound pressure 17-fold. A total amplification factor of 22 is achieved through the lever action of the ossicular chain. If the ossicular chain fails to transform the sound pressure between the tympanic membrane and the footplate of the stapes, the patient will experience conductive hearing loss of magnitude 20 dB.

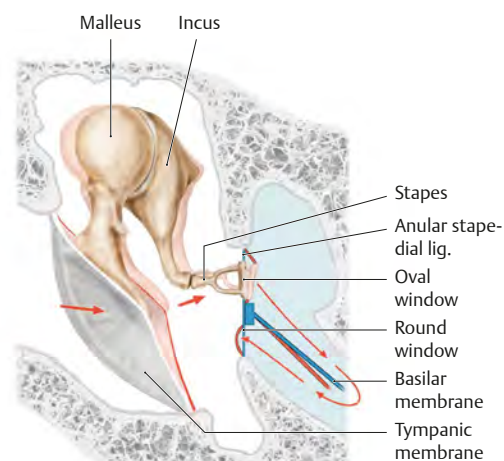
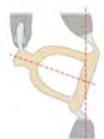


A Vibration of the tympanic membrane causes a rocking movement in the ossicular chain. The mechanical advantage of the lever action of the ossicular chain amplifies the sound waves by a factor of 1.3.

B The stapes in its normal position lies in the plane of the oval window.



C Rocking of the ossicular chain causes the stapes to tilt. The movement of the stapes base against the membrane of the oval window (stapedial membrane) induces corresponding waves in the fluid column of the inner ear.



D Propagation of sound waves by the ossicular chain.

Arteries of the Middle Ear

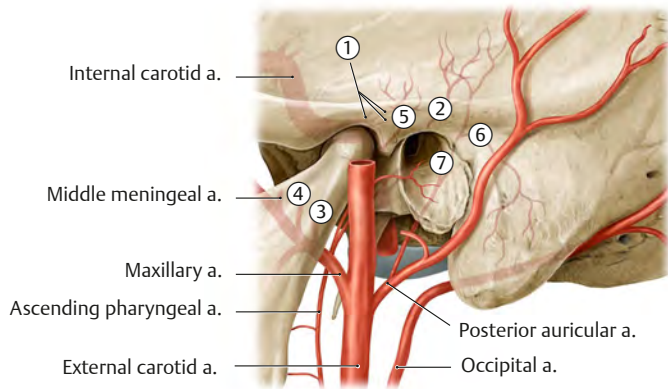


Table 44.2 Principal arteries of the middle ear		
Origin	Artery	Distribution
Internal carotid a.	① Caroticotympanic aa.	Tympanic cavity (anterior wall), pharyngotympanic (auditory) tube
External carotid a.	Ascending pharyngeal a. (medial br.)	② Inferior tympanic a. Tympanic cavity (floor), promontory
	Maxillary a. (terminal br.)	③ Deep auricular a. Tympanic cavity (floor), tympanic membrane
		④ Anterior tympanic a. Tympanic membrane, mastoid antrum, malleus, incus
	Middle meningeal a.	⑤ Superior tympanic a. Tympanic cavity (roof), tensor tympani, stapes
	Posterior auricular a. (posterior br.)	⑥ Stylomastoid a. Tympanic cavity (posterior wall), mastoid air cells, stapedius m., stapes
	Stylomastoid a.	⑦ Posterior tympanic a. Chorda tympani, tympanic membrane, malleus

Fig. 44.17 Arteries of the middle ear: Ossicular chain and tympanic membrane

Medial view of the right tympanic membrane. With inflammation, the arteries of the tympanic membrane may become so dilated that their course can be observed (as shown here).

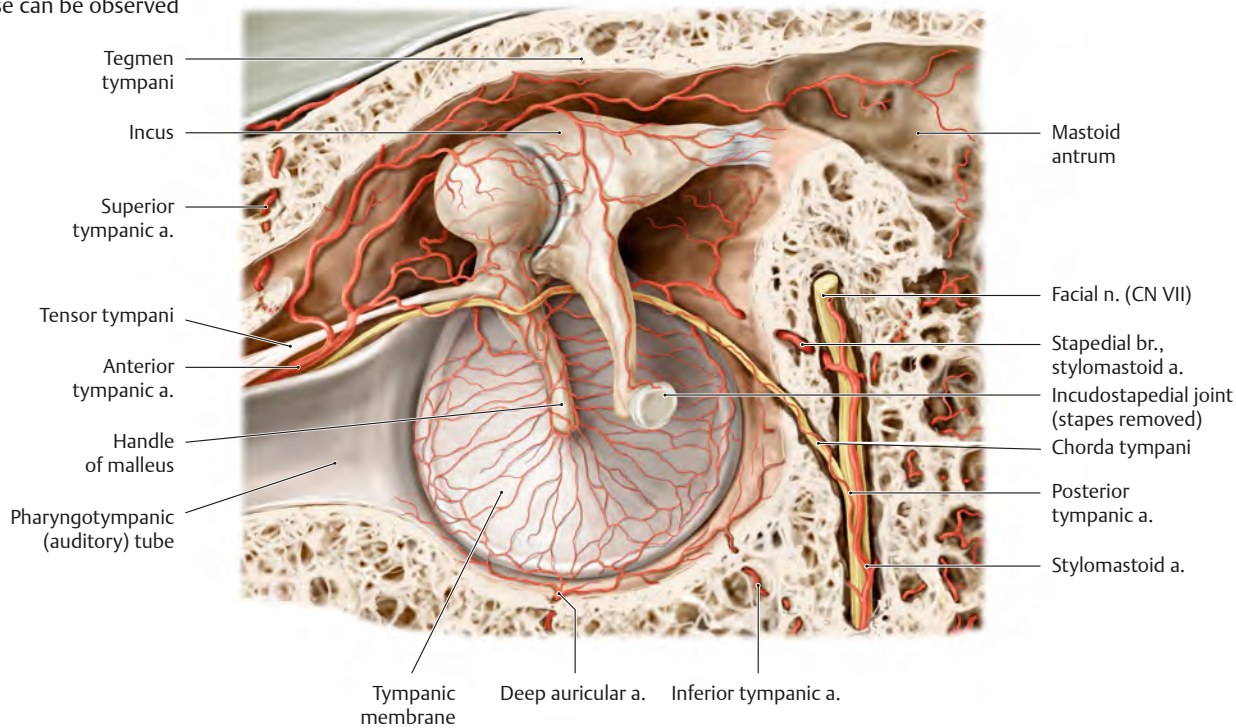
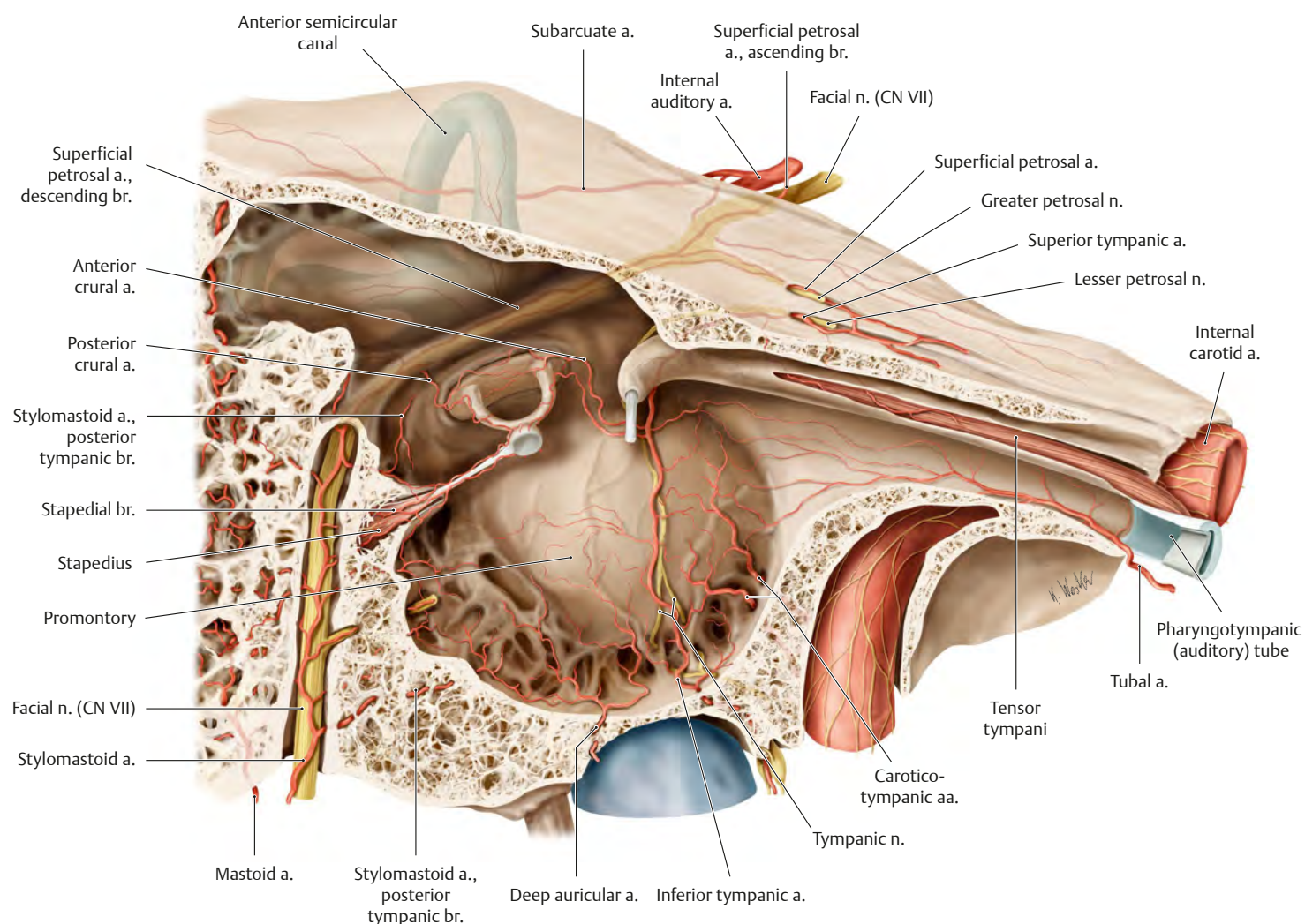


Fig. 44.18 Arteries of the middle ear: Tympanic cavity

Right petrous bone, anterior view. *Removed:* Malleus, incus, portions of chorda tympani, and anterior tympanic artery.

**Clinical box 44.4****Otitis Media**

Otitis media is an infection of the middle ear that occurs commonly in children often following an upper respiratory tract infection. Fluid that accumulates in the middle ear can temporarily diminish hearing and inflammation of the lining of the tympanic cavity can block the pharyngotympanic tube.

Hyperacusis

The stapedius muscle protects the delicate inner ear by modifying the vibrations of very loud sounds as they are transmitted through the middle ear to the stapes. Paralysis of the muscle resulting from a lesion of the facial nerve causes an extreme sensitivity to sound, a condition known as hyperacusis.

Inner Ear

The inner ear consists of the vestibular apparatus (for balance) and the auditory apparatus (for hearing). Both are formed by a membranous

labyrinth filled with endolymph floating within a bony labyrinth filled with perilymph and embedded in the petrous part of the temporal bone.

Fig. 44.19 Vestibular apparatus

Right lateral view.

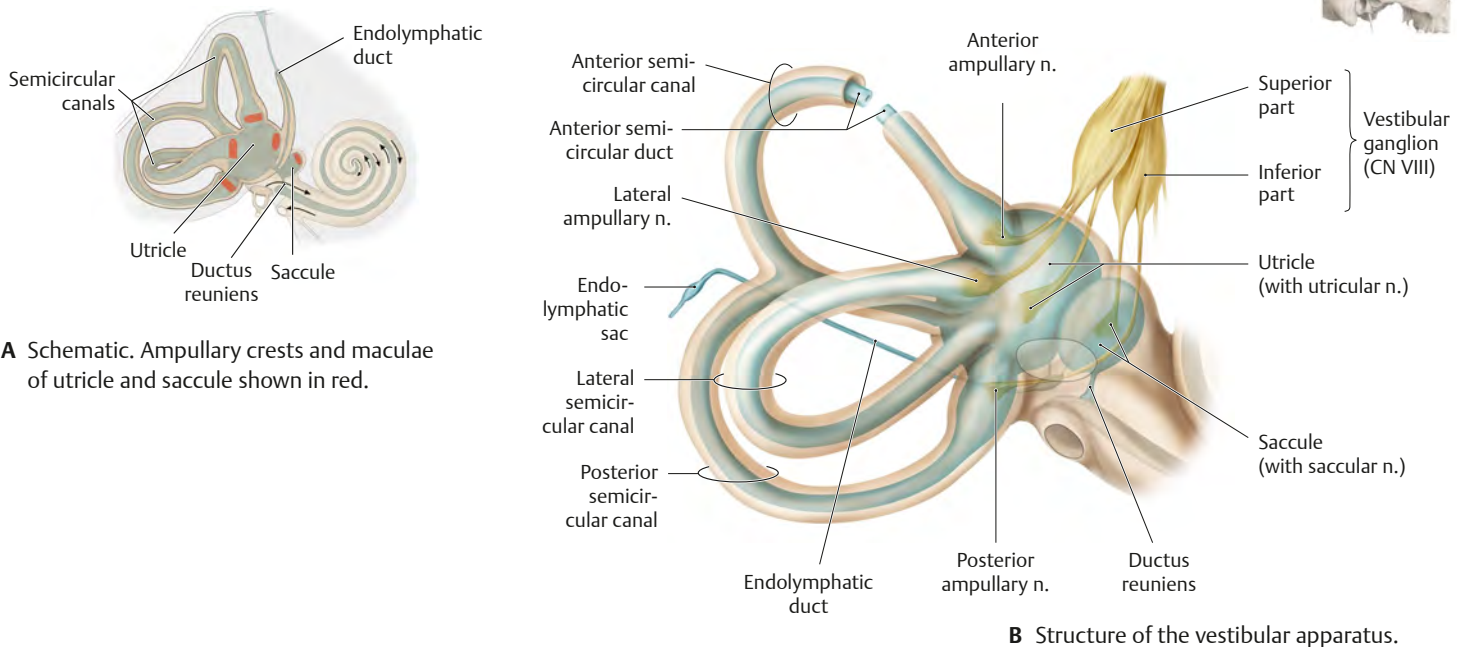


Fig. 44.20 Auditory apparatus

The cochlear labyrinth and its bony shell form the cochlea, which contains the sensory epithelium of the auditory apparatus (organ of Corti).

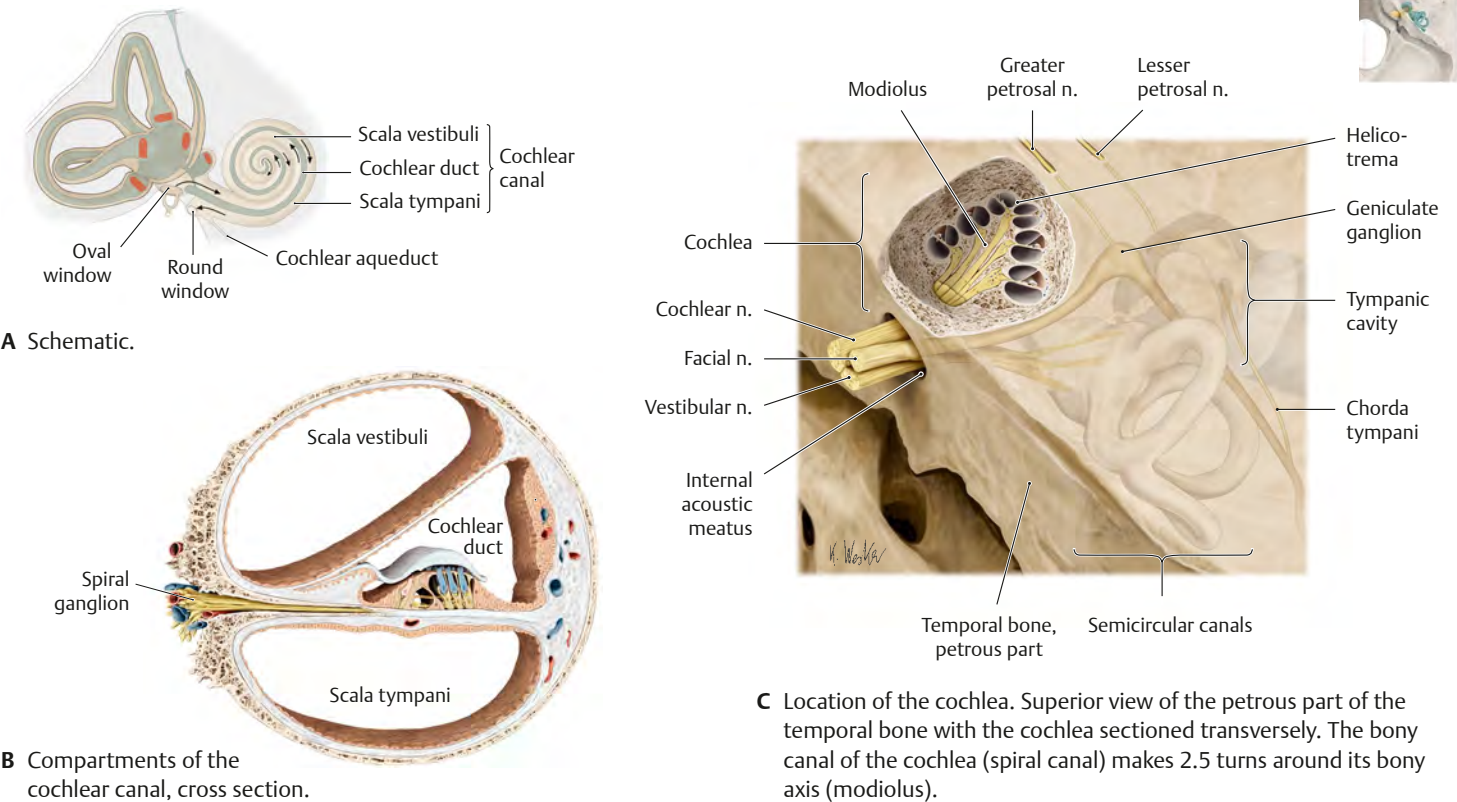
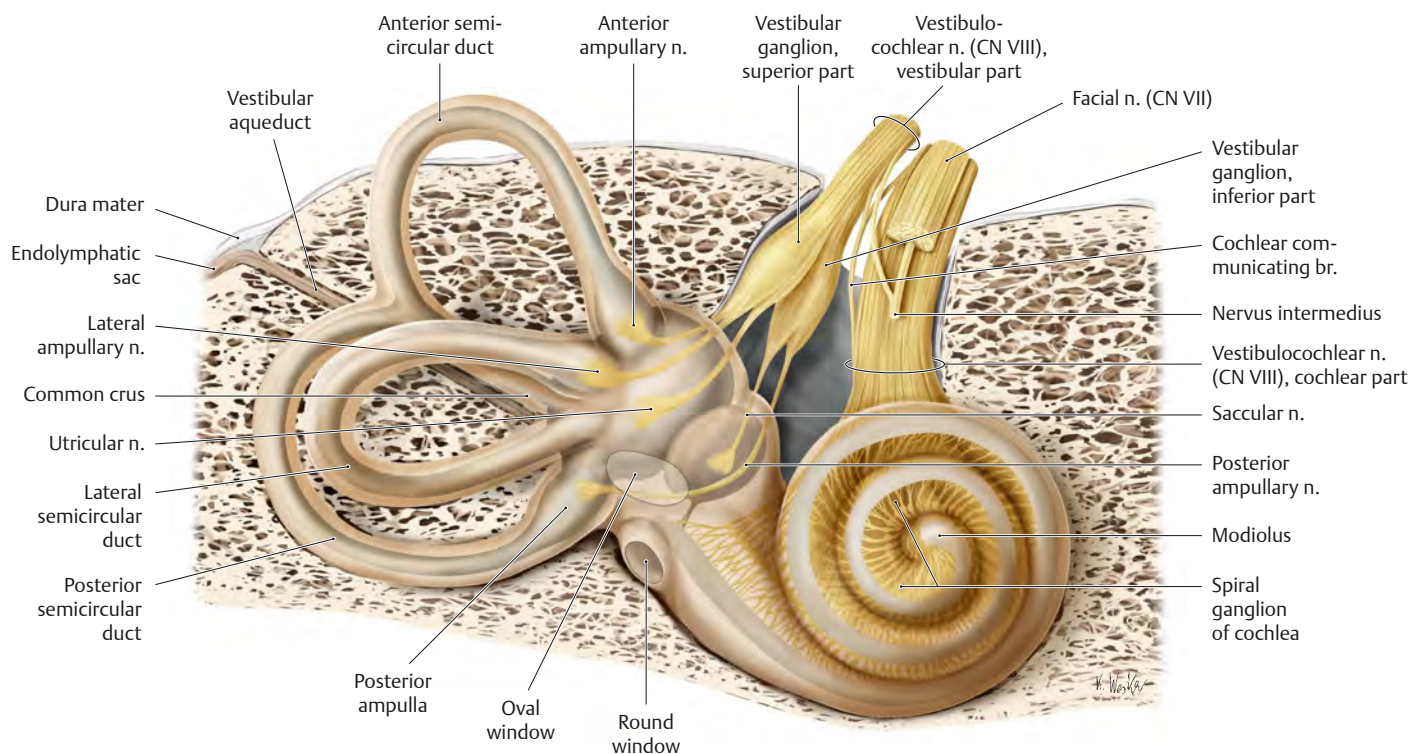


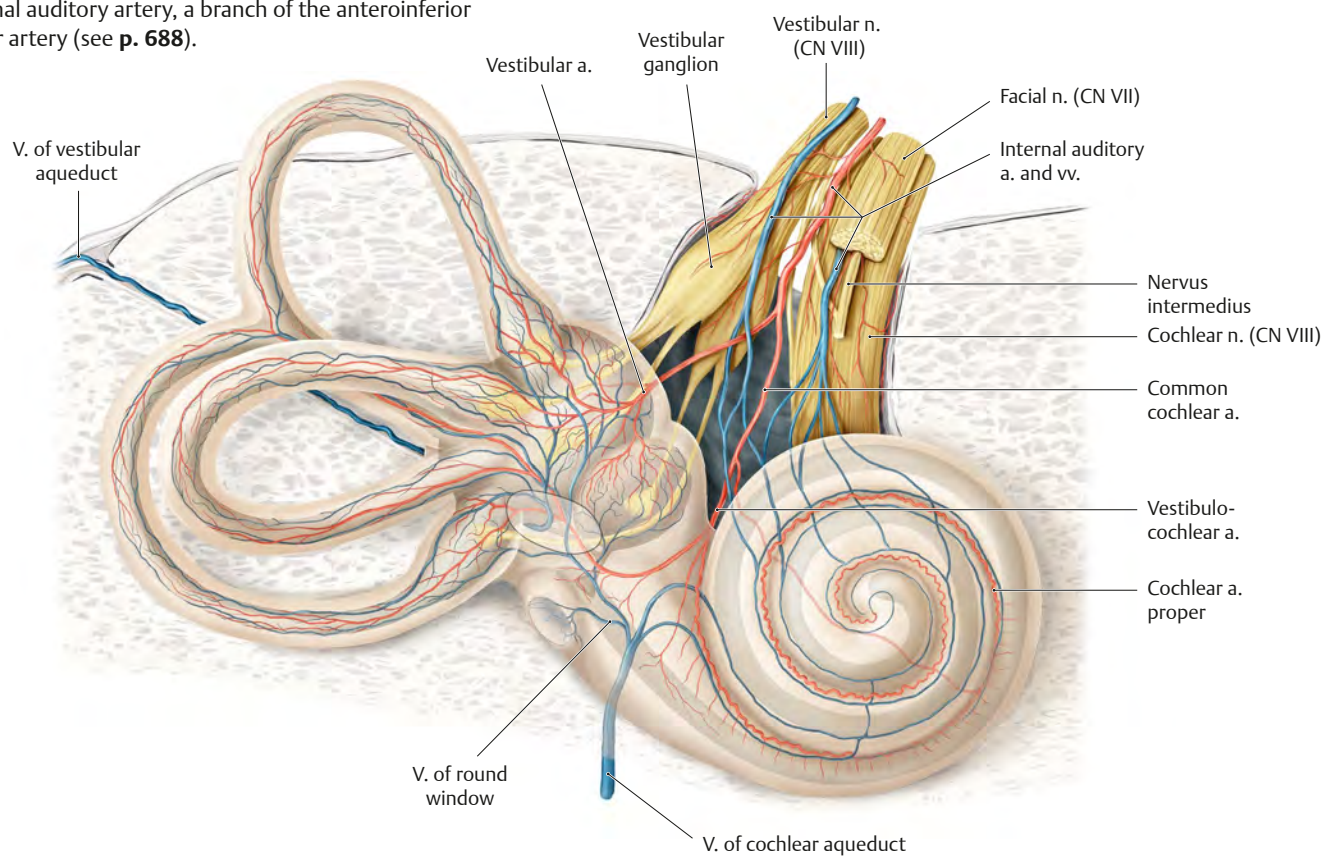
Fig. 44.21 Innervation of the membranous labyrinth

Right ear, anterior view. The vestibulocochlear nerve (CN VIII; see p. 570) transmits afferent impulses from the inner ear to the brainstem through the internal acoustic meatus. The vestibulocochlear nerve is

divided into the vestibular and cochlear nerves. *Note:* The sensory organs in the semicircular canals respond to angular acceleration, and the macular organs respond to horizontal and vertical linear acceleration.

**Fig. 44.22 Blood vessels of the inner ear**

Right anterior view. The labyrinth receives its blood supply from the internal auditory artery, a branch of the anteroinferior cerebellar artery (see p. 688).

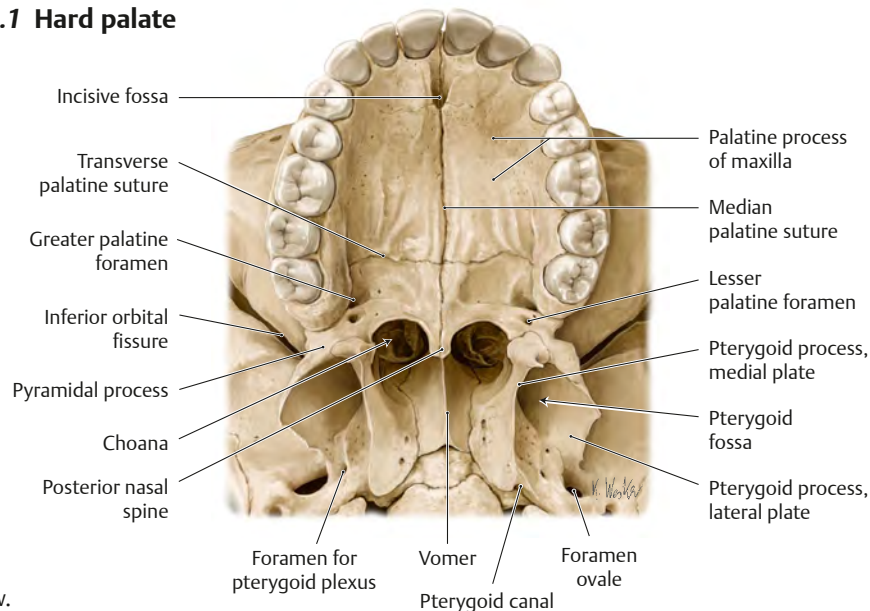


45 Oral Cavity & Pharynx

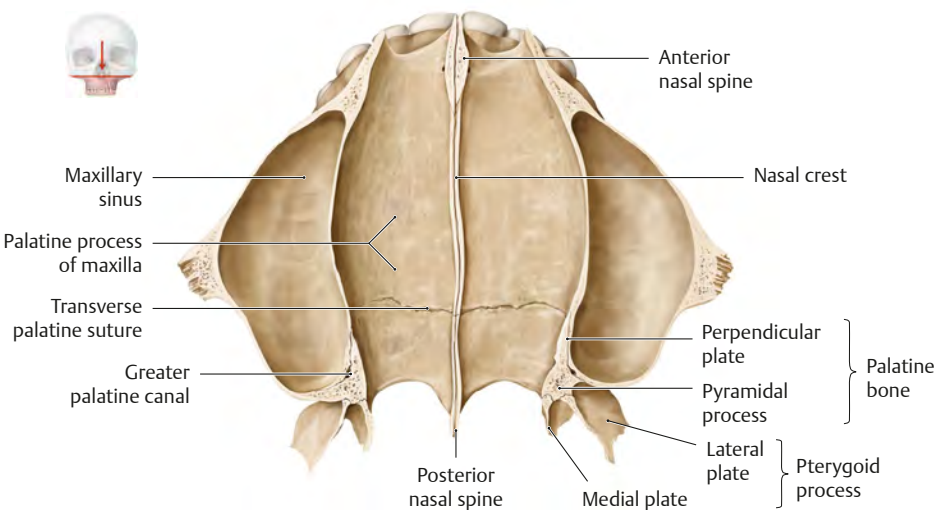
Bones of the Oral Cavity

The floor of the nasal cavity (the maxilla and palatine bone) forms the roof of the oral cavity, the hard palate. The two horizontal processes of the maxilla (the palatine processes) grow together during development, eventually fusing at the median palatine suture. Failure to fuse results in a cleft palate.

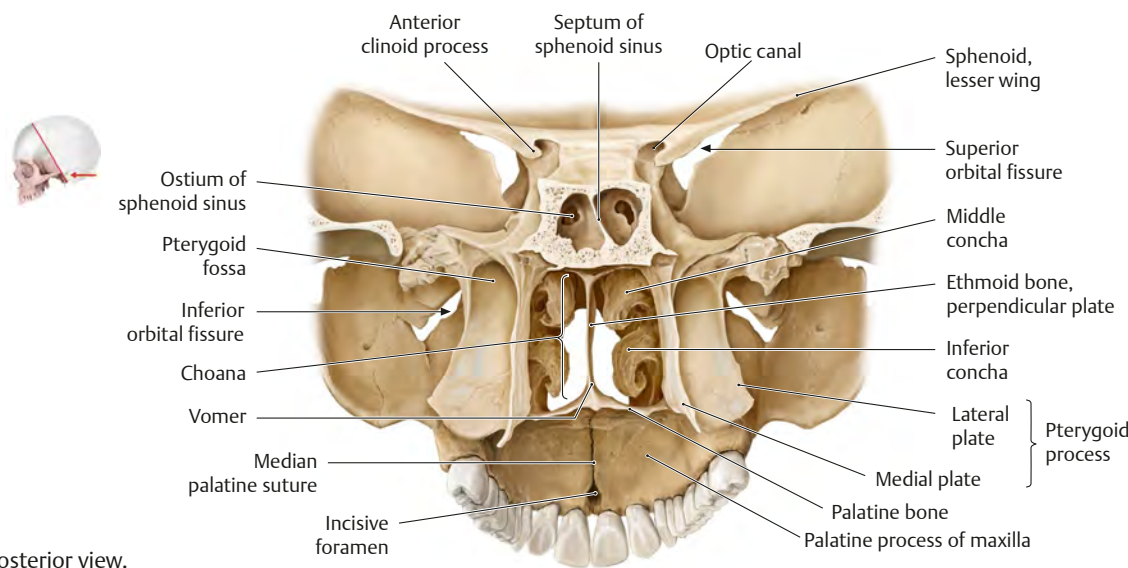
Fig. 45.1 Hard palate



A Inferior view.



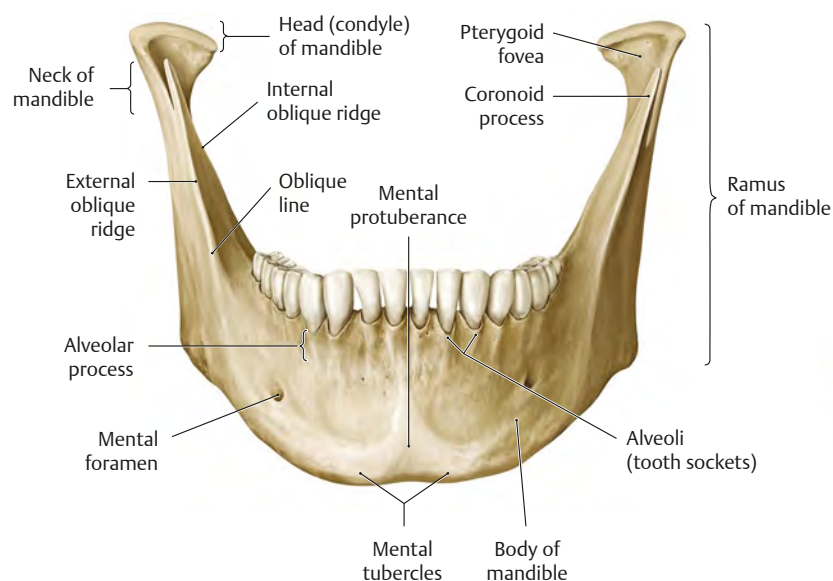
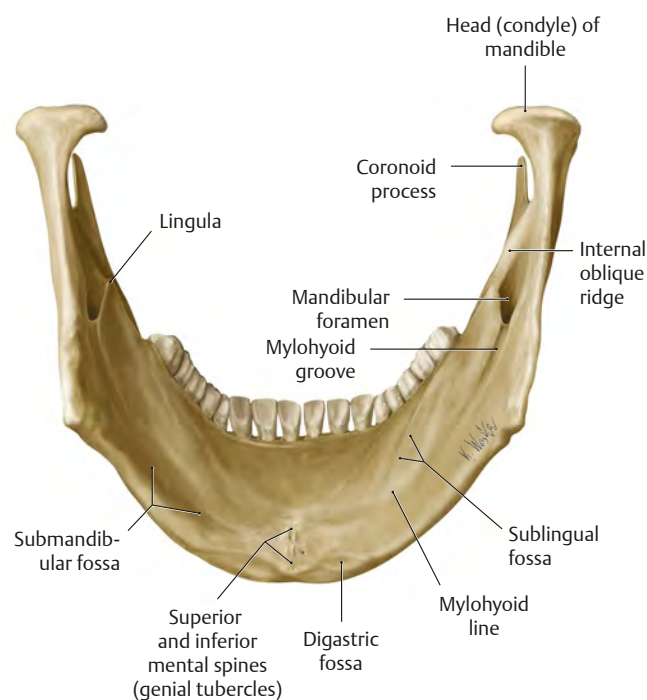
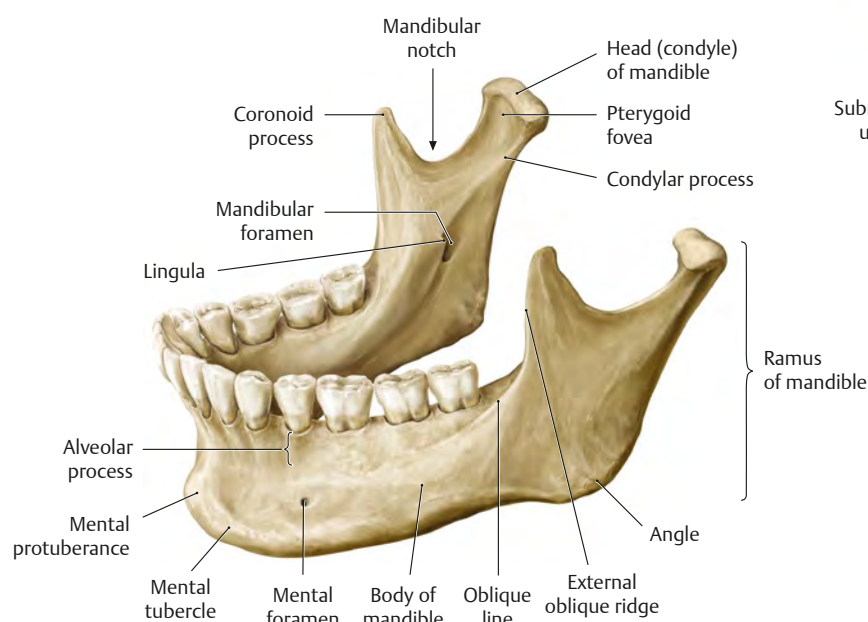
B Superior view.
Removed: Maxilla (upper part).



C Oblique posterior view.

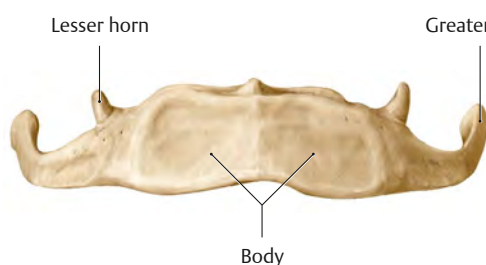
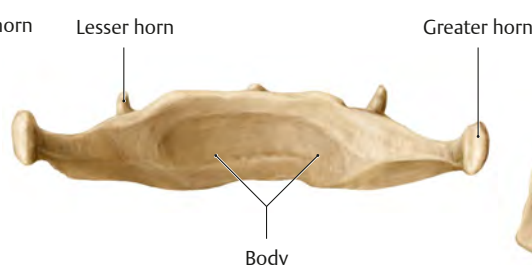
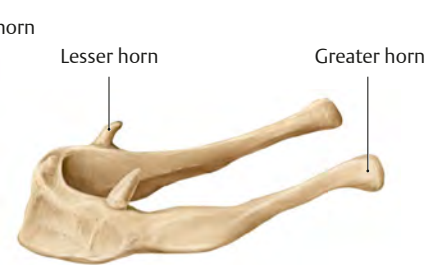
Fig. 45.2 Mandible

The mandible (jaw) is connected to the viscerocranium at the temporomandibular joint (p. 638).

**A** Anterior view.**B** Posterior view.**C** Oblique left lateral view.**Fig. 45.3 Hyoid bone**

The hyoid bone is suspended in the neck by muscles between the floor of the mouth and the larynx. Although not listed among the cranial

bones, the hyoid bone gives attachment to the muscles of the oral floor. The greater horn and body of the hyoid are palpable in the neck.

**A** Anterior view.**B** Posterior view.**C** Oblique left lateral view.

Temporomandibular Joint

Fig. 45.4 Temporomandibular joint

The head of the mandible articulates with the mandibular fossa in the temporomandibular joint.

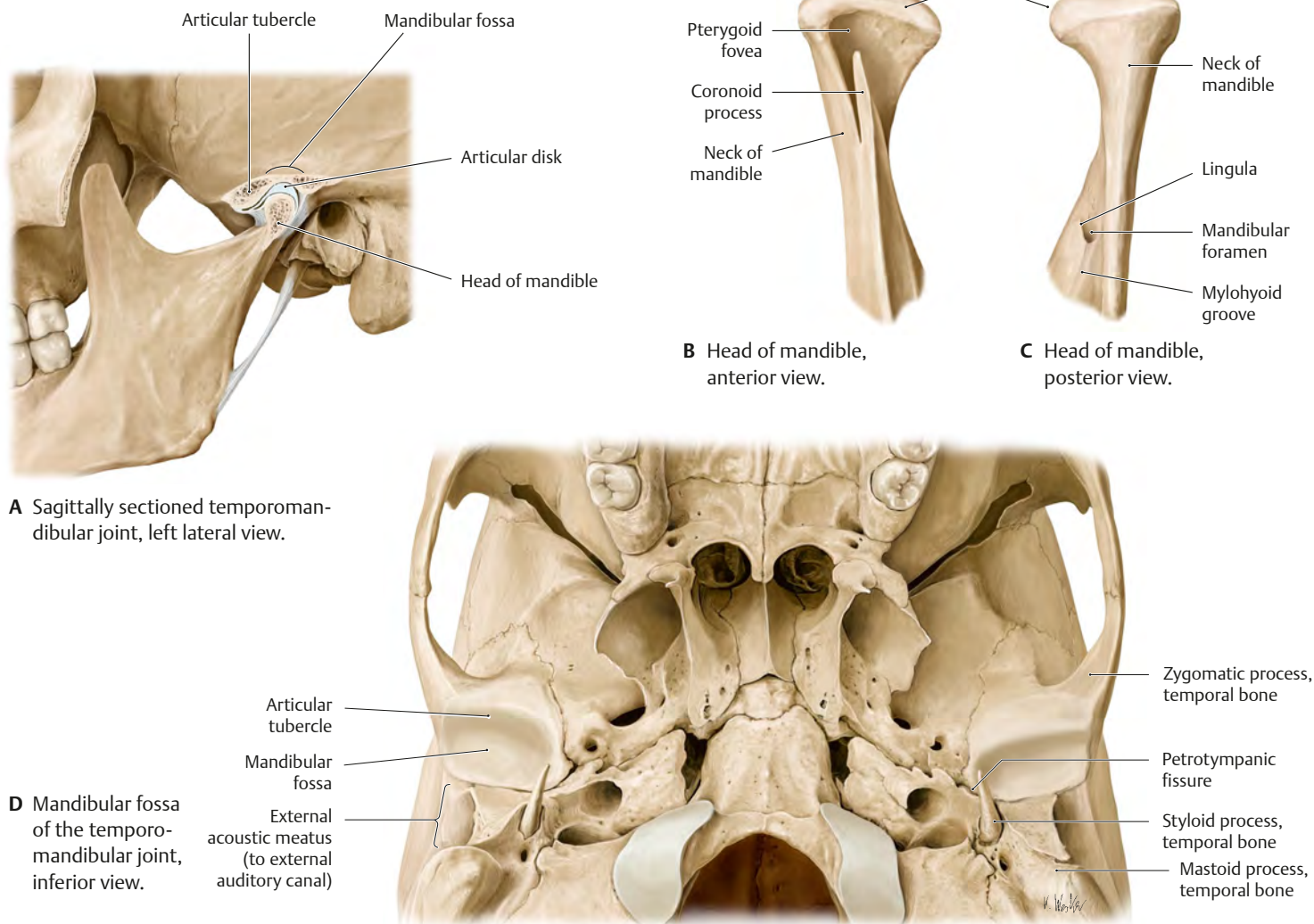


Fig. 45.5 Ligaments of the temporomandibular joint

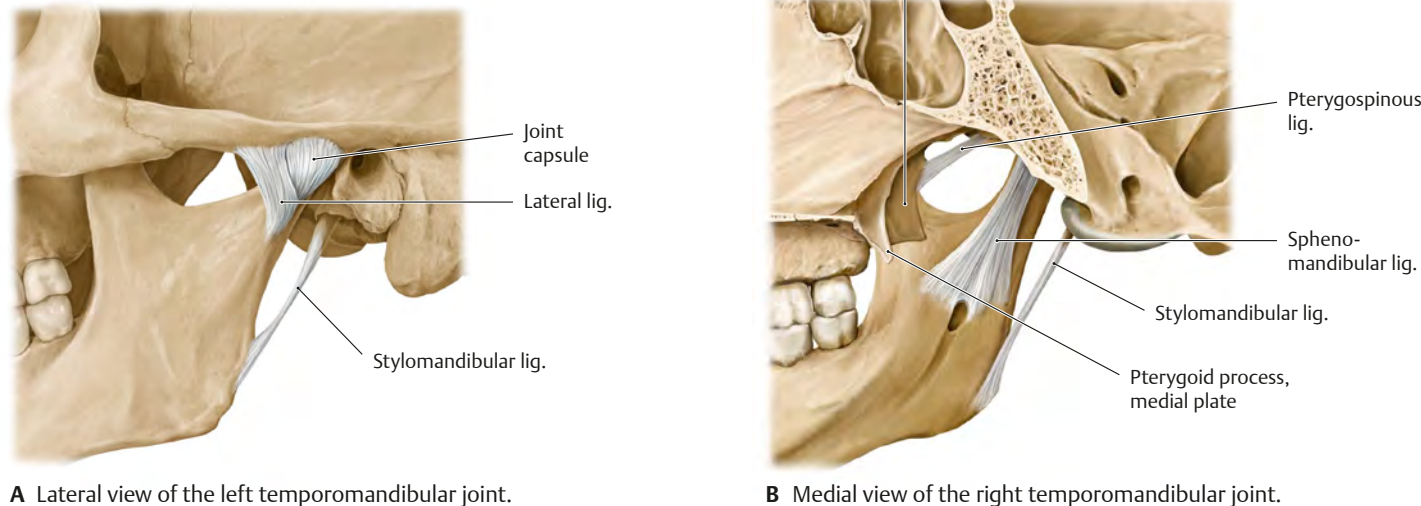
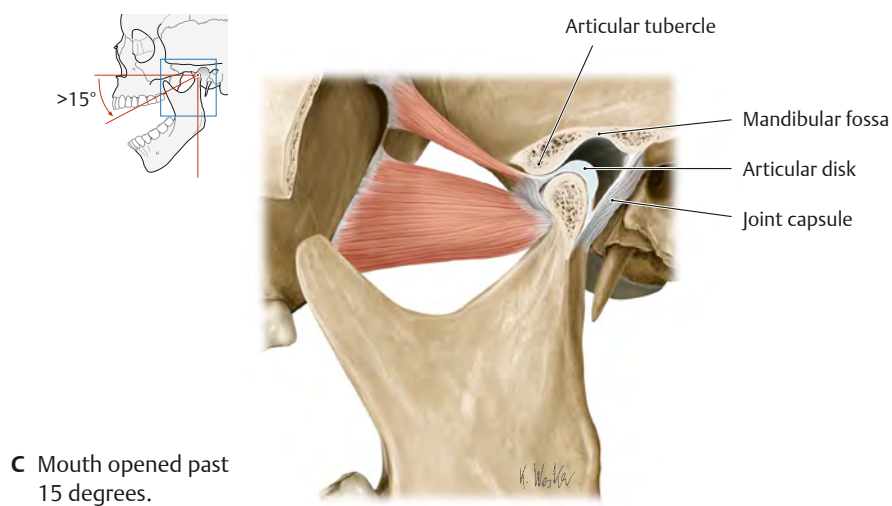
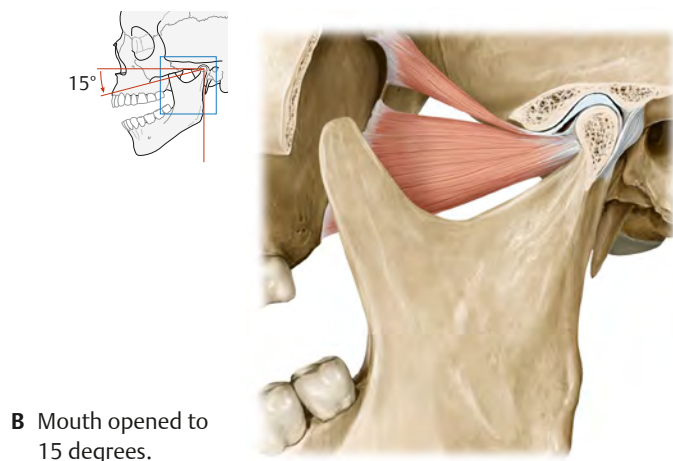
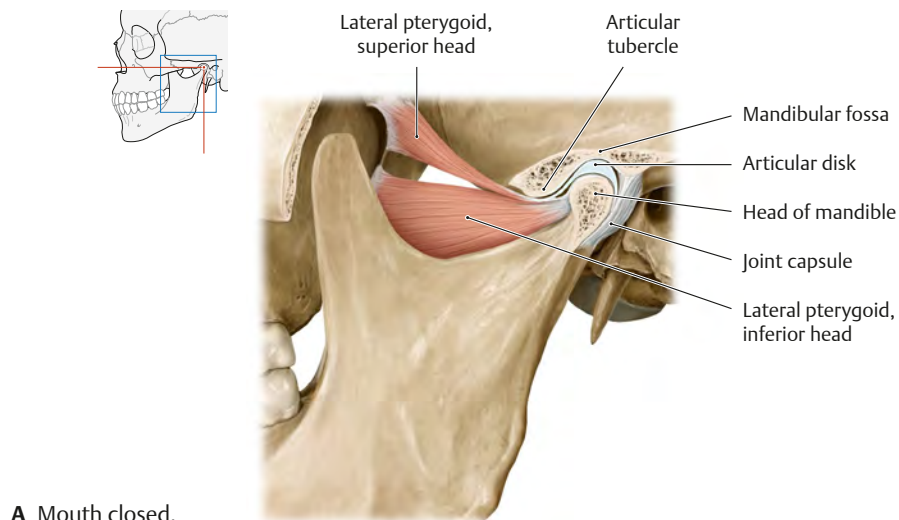


Fig. 45.6 Movement of the temporomandibular joint

Left lateral view. During the first 15 degrees of mandibular depression (opening of the mouth), the head of the mandible remains in the mandibular fossa. Past 15 degrees, the head of the mandible glides forward onto the articular tubercle.

**Clinical box 45.1****Dislocation of the temporomandibular joint**

Dislocation may occur if the head of the mandible slides past the articular tubercle. The mandible then becomes locked in a protruded position, a condition reduced by pressing on the mandibular row of teeth.

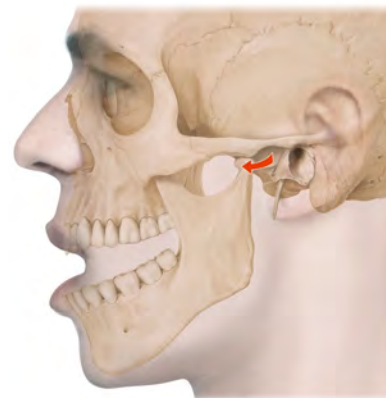
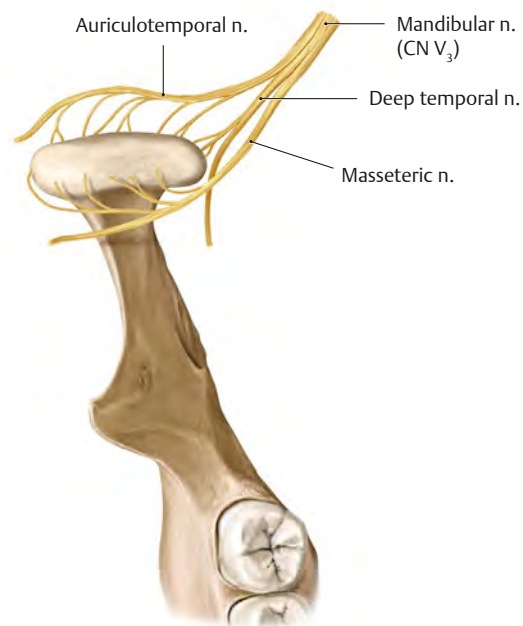


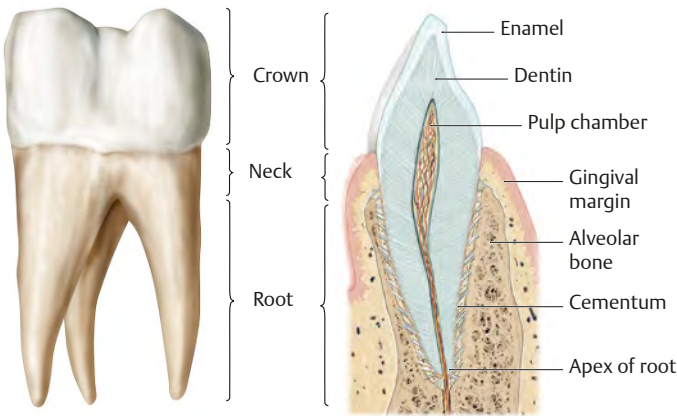
Fig. 45.7 Innervation of the temporomandibular joint capsule
Superior view.



Teeth

Fig. 45.8 Structure of a tooth

Each tooth consists of hard tissue (enamel, dentin, cementum) and soft tissue (dental pulp) arranged into a crown, neck (cervix), and root.

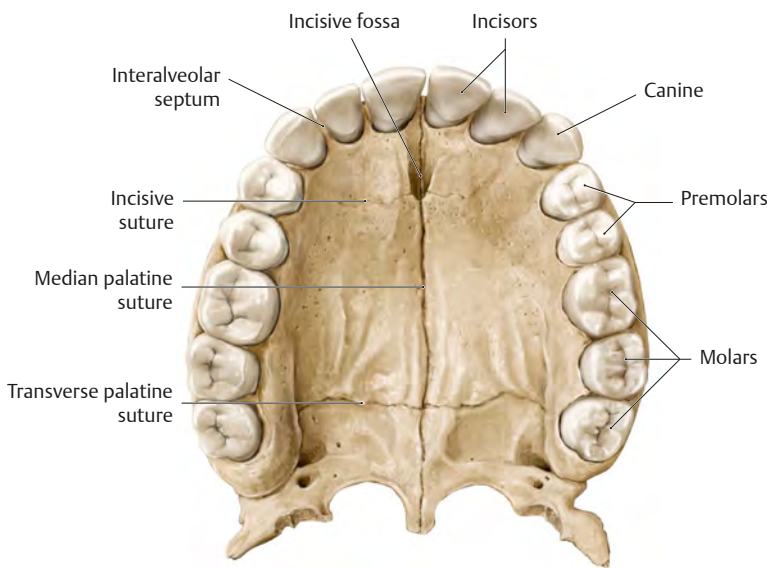


A Principal parts of a tooth (molar).

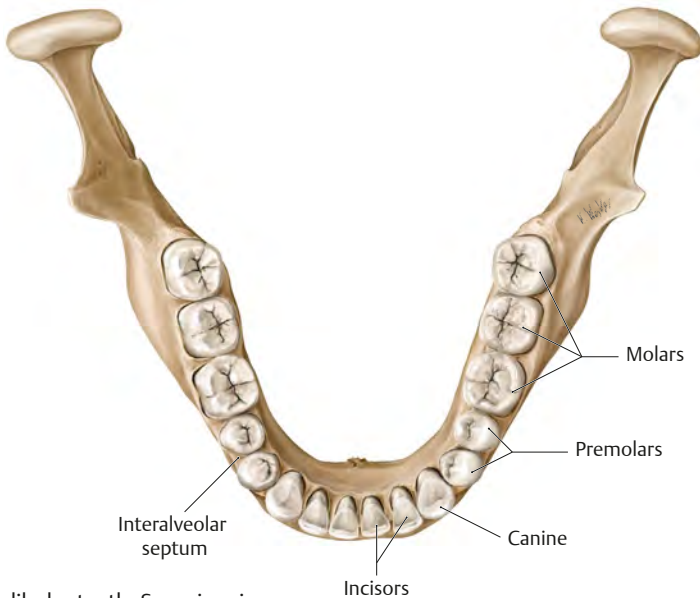
B Histology of a tooth (mandibular incisor).

Fig. 45.9 Permanent teeth

Each half of the maxilla and mandible contains a set of three anterior teeth (two incisors, one canine) and five posterior (postcanine) teeth (two premolars, three molars).



A Maxillary teeth. Inferior view of the maxilla.



B Mandibular teeth. Superior view of the mandible.

Fig. 45.10 Tooth surfaces

The top of the tooth is known as the occlusal surface.

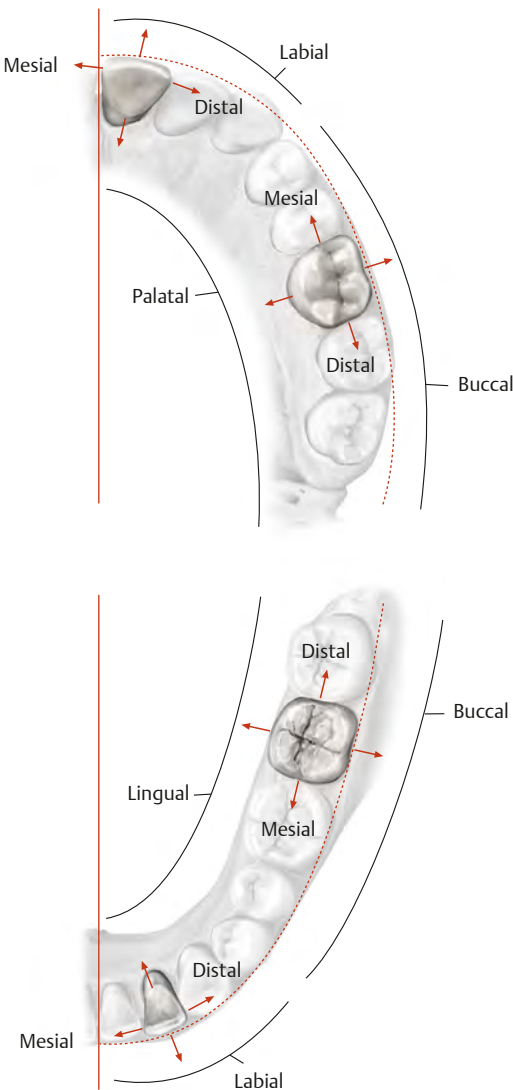
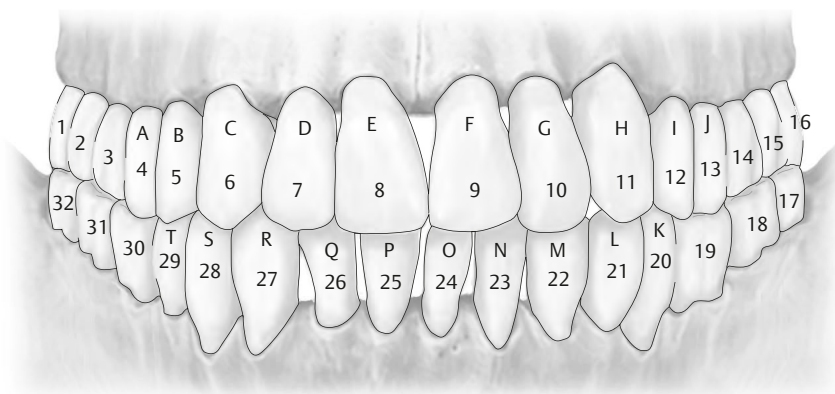


Fig. 45.11 Coding of the teeth

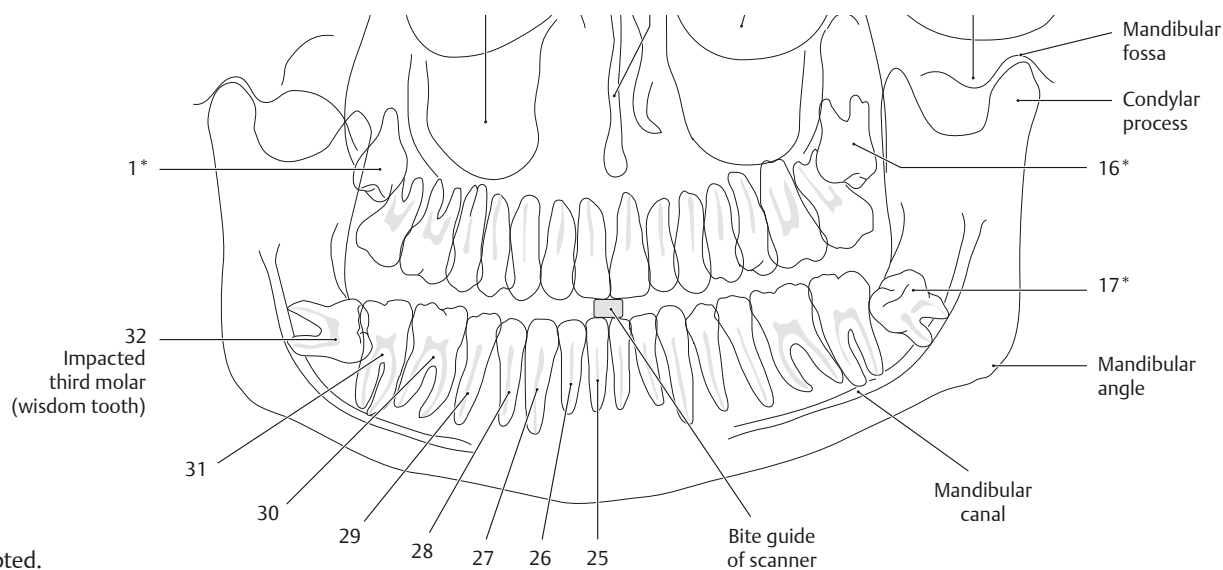
In the United States, the 32 permanent teeth are numbered sequentially (not assigned to quadrants). The 20 deciduous (baby) teeth are coded A to J (upper arch), and K to T (lower arch), in a similar clock-

wise fashion. The third upper right molar is 1; the second upper right premolar is A.

**Fig. 45.12 Dental panoramic tomogram**

The dental panoramic tomogram (DPT) is a survey radiograph that allows preliminary assessment of the temporomandibular joints, maxillary sinuses, maxillomandibular bone, and dental status (carious lesions,

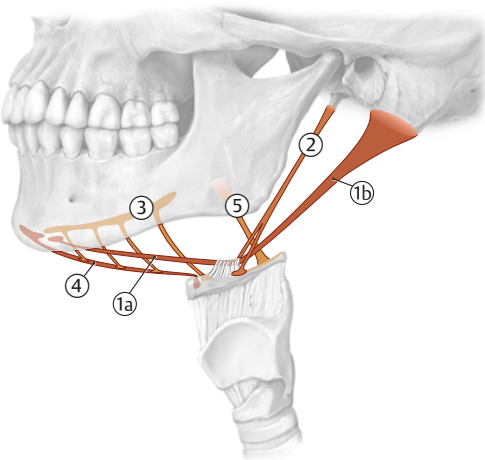
location of wisdom teeth, etc.). DPT courtesy of Dr. U. J. Rother, Director of the Department of Diagnostic Radiology, Center for Dentistry and Oromaxillo-facial Surgery, Eppendorf University Medical Center, Hamburg, Germany.



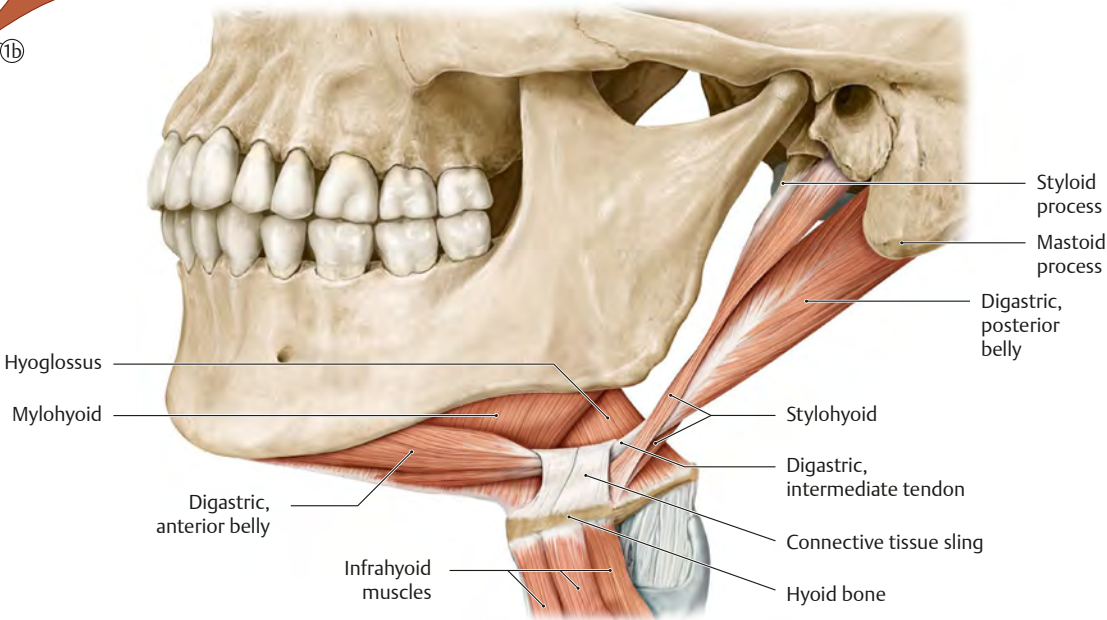
*Not fully erupted.

Oral Cavity Muscle Facts

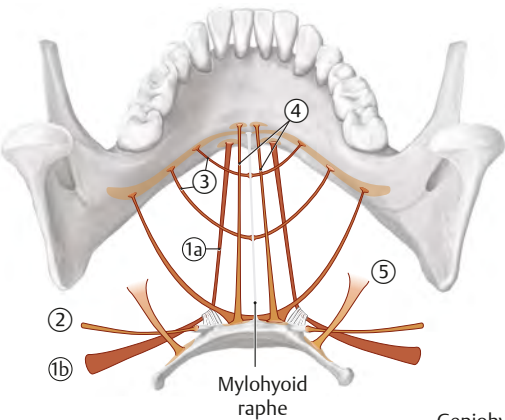
Fig. 45.13 Muscles of the oral floor
See pp. 516–517 for the infrahyoid muscles.



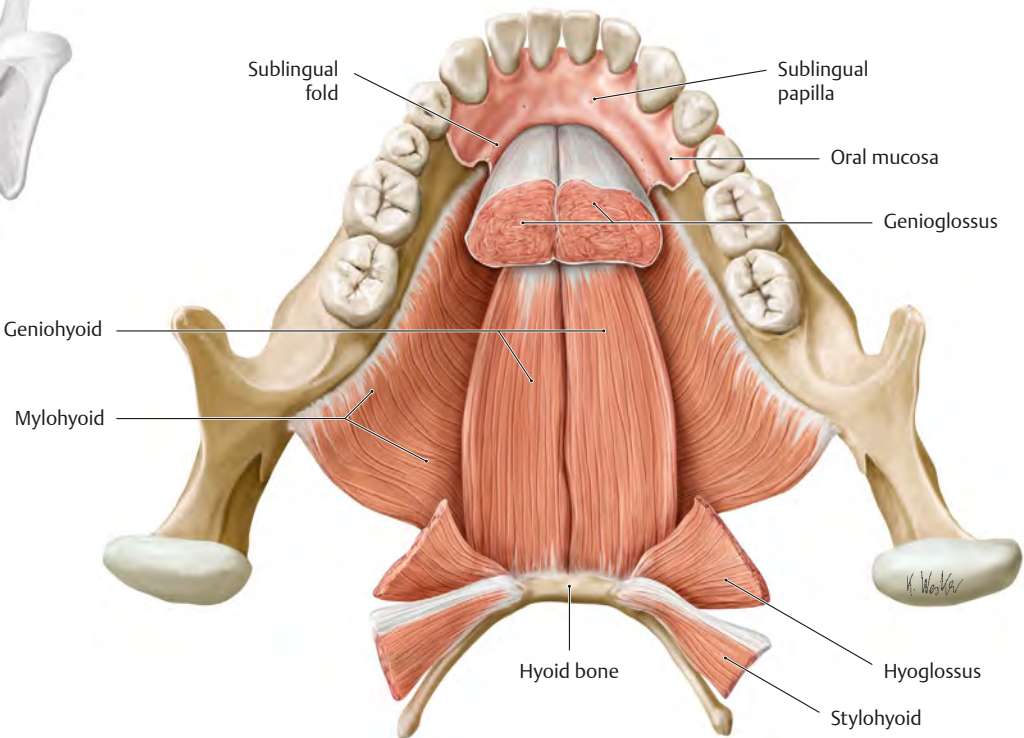
A Suprahyoid muscles, left lateral view.



B Left lateral view.



C Suprahyoid muscles, superior view.



D Superior view of the mandible and hyoid bone.

Table 45.1

Suprahyoid muscles

Muscle	Origin	Insertion	Innervation	Action
① Digastric	⑬ Anterior belly	Mandible (digastric fossa)	Mylohyoid n. (from CN V ₃)	Elevates hyoid bone (during swallowing), assists in opening mandible
	⑭ Posterior belly	Temporal bone (mastoid notch, medial to mastoid process)	Facial n. (CN VII)	
② Stylohyoid	Temporal bone (styloid process)	Hyoid bone (body)	Via a split tendon	Tightens and elevates oral floor, draws hyoid bone forward (during swallowing), assists in opening mandible and moving it side to side (mastication)
③ Mylohyoid	Mandible (mylohyoid line)		Via median tendon of insertion (mylohyoid raphe)	
④ Geniohyoid	Mandible (inferior mental spine)		Anterior ramus of C1 via hypoglossal n. (CN XII)	
⑤ Hyoglossus	Hyoid bone (superior border of greater cornu)	Sides of tongue	Hypoglossal n. (CN XII)	Depresses and retracts the tongue

Fig. 45.14 Muscles of the soft palate

Inferior view. The soft palate forms the posterior boundary of the oral cavity, separating it from the oropharynx.

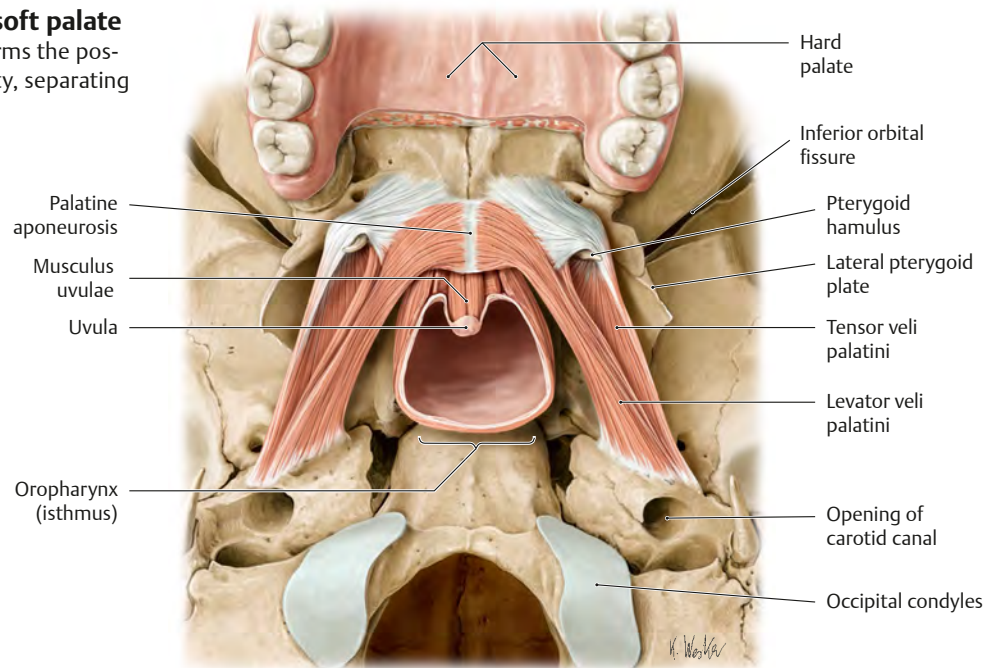


Table 45.2

Muscles of the soft palate

Muscle	Origin	Insertion	Innervation	Action
Tensor veli palatini	Medial pterygoid plate (scaphoid fossa); sphenoid bone (spine); cartilage of pharyngotympanic tube	Palatine aponeurosis	Medial pterygoid n. (CN V ₃)	Tightens soft palate; opens inlet to pharyngotympanic (auditory) tube (during swallowing, yawning)
Levator veli palatini	Cartilage of pharyngotympanic tube; temporal bone (petrous part)			Raises soft palate to horizontal position
Musculus uvulae	Uvula (mucosa)	Palatine aponeurosis; posterior nasal spine	Vagus n. via pharyngeal plexus	Shortens and raises uvula
Palatoglossus*				Elevates tongue (posterior portion); pulls soft palate onto tongue
Palatopharyngeus*	Tongue (side)	Palatine aponeurosis		Tightens soft palate; during swallowing pulls pharyngeal walls superiorly, anteriorly, and medially

*For the palatoglossus, see Figs. 45.19, p. 646 and 45.24, p. 648; and for the palatopharyngeus, see Figs. 45.24, p. 648 and 45.29C, p. 653.

Innervation of the Oral Cavity

Fig. 45.15 Trigeminal nerve in the oral cavity
Right lateral view.

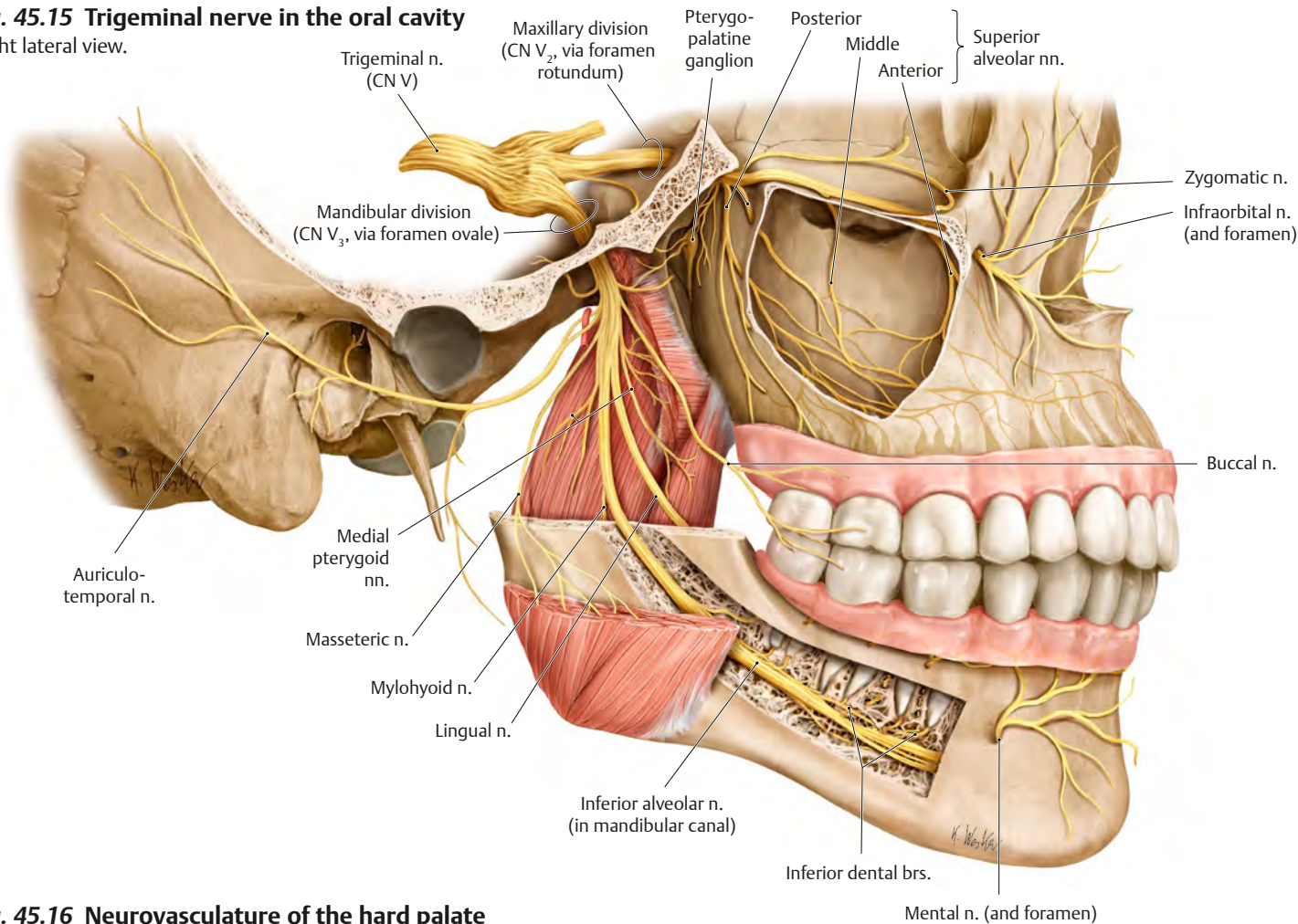
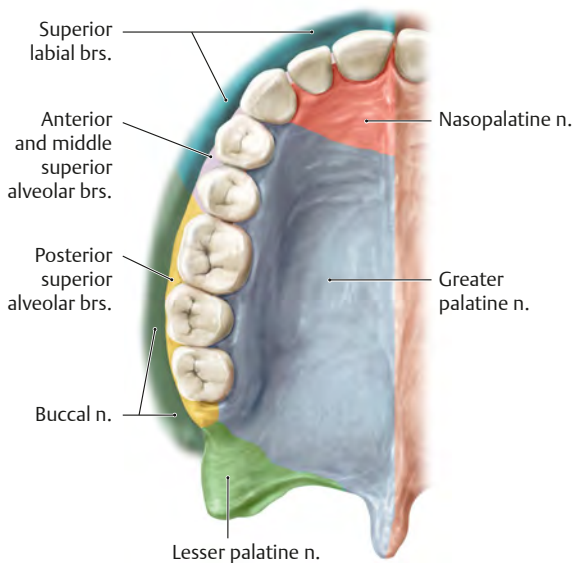
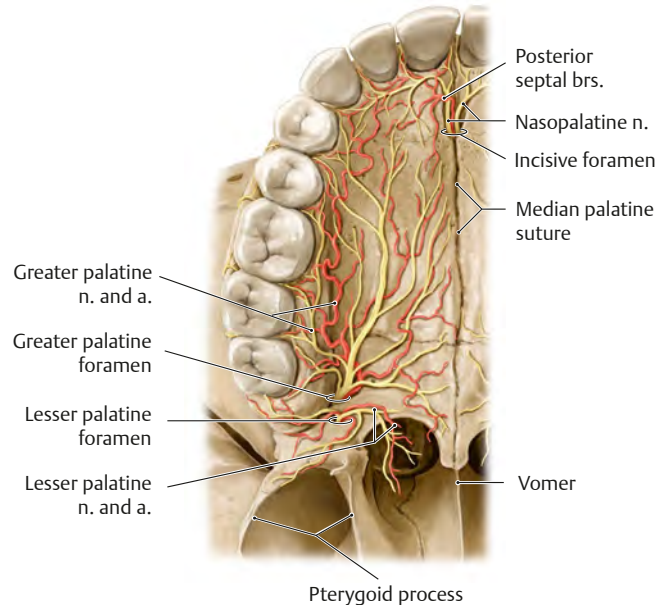


Fig. 45.16 Neurovasculature of the hard palate
Inferior view. The hard palate receives sensory innervation primarily from terminal branches of the maxillary division of the trigeminal nerve (CN V₂). The arteries of the hard palate arise from the maxillary artery.

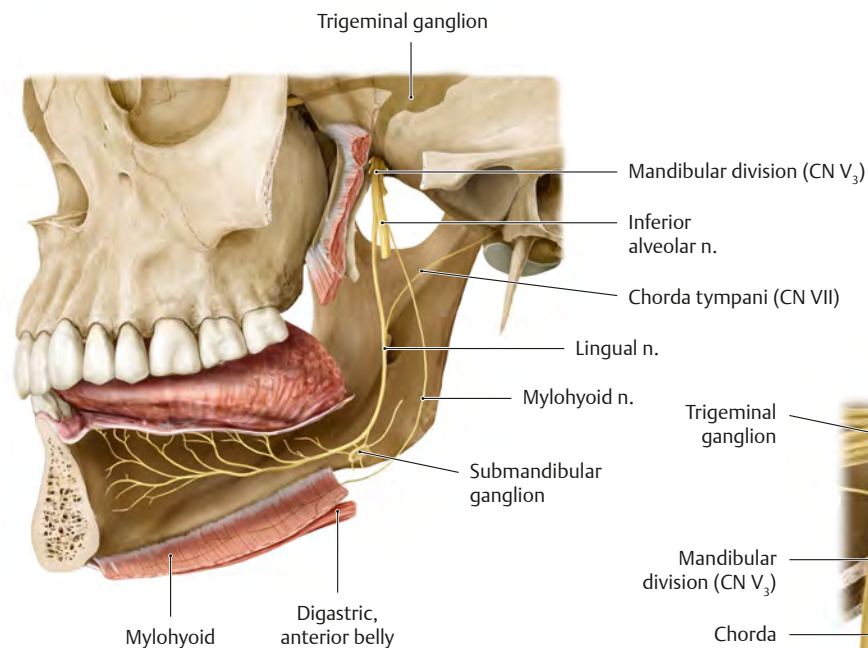


A Sensory innervation. *Note:* The buccal nerve is a branch of the mandibular division (CN V₃).

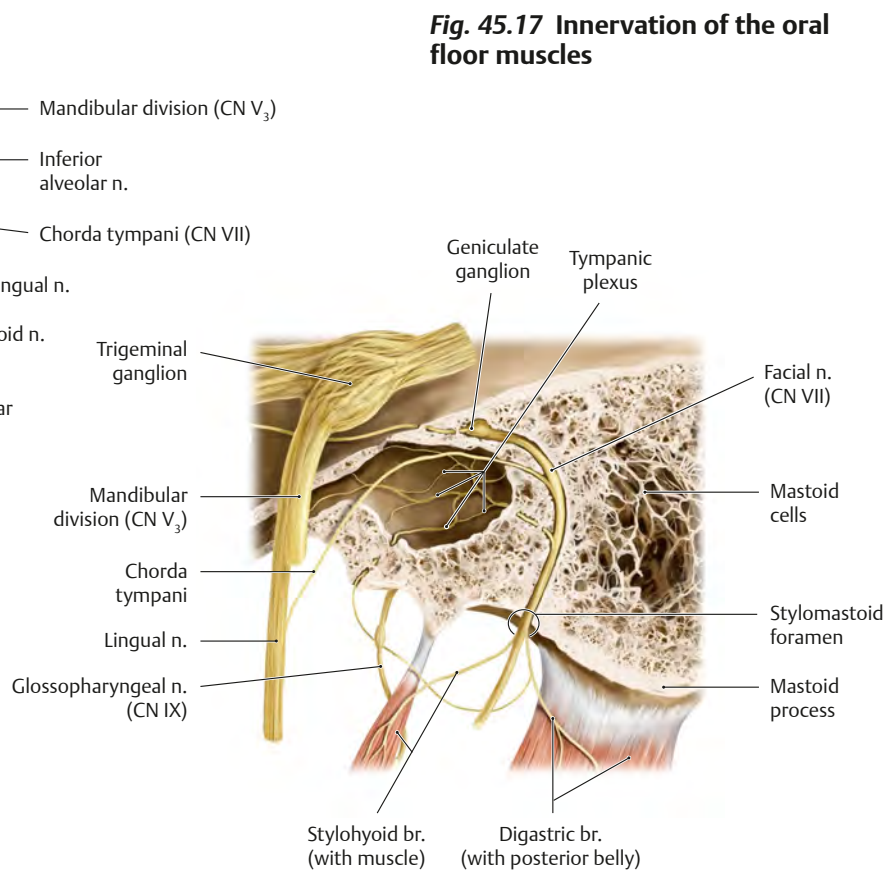


B Nerves and arteries.

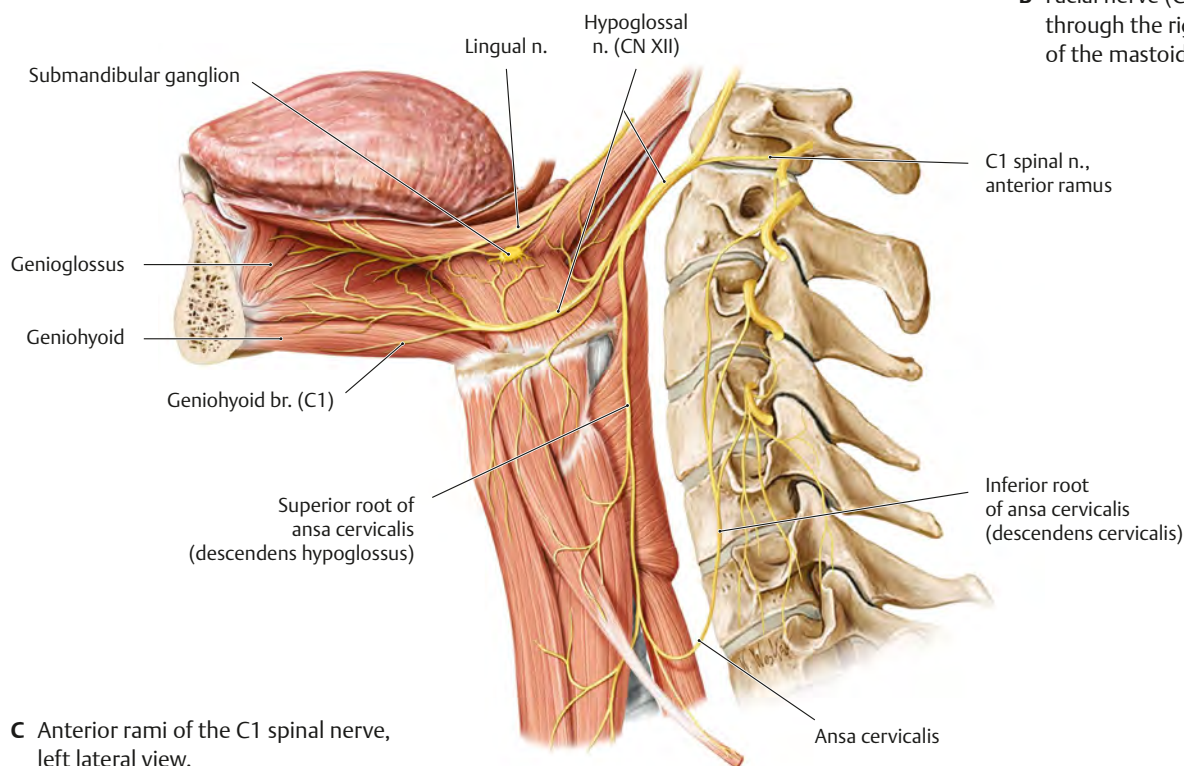
The muscles of the oral floor have a complex nerve supply with contributions from the trigeminal nerve (CN V₃), facial nerve (CN VII), and C1 spinal nerve via the hypoglossal nerve (CN XII).



A Mylohyoid nerve (CN V₃). Left lateral view with the left half of the mandible removed.



B Facial nerve (CN VII). Sagittal section through the right petrous bone at the level of the mastoid process, medial view.



C Anterior rami of the C1 spinal nerve, left lateral view.

Tongue

The dorsum of the tongue is covered by a highly specialized mucosa that supports its sensory functions (taste and fine tactile discrimination). The tongue is endowed with a very powerful muscular body to

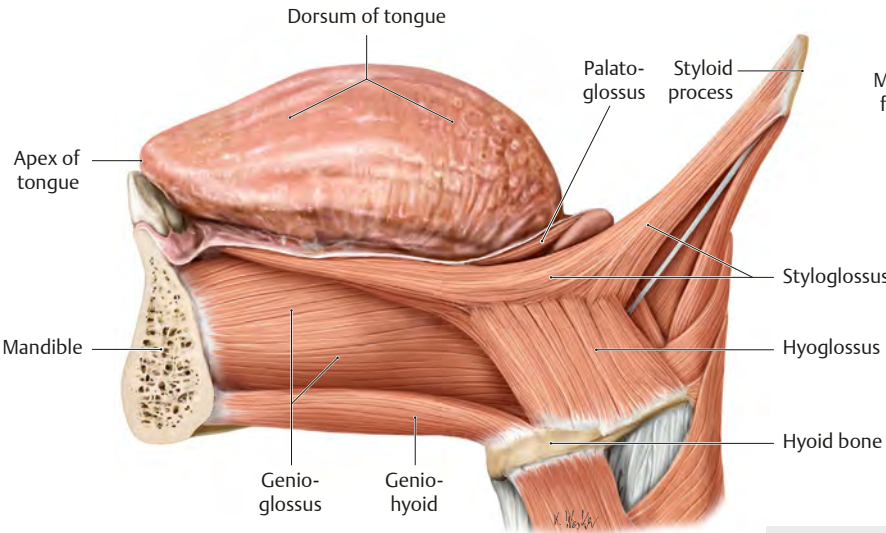
support its motor properties during mastication, swallowing, and speaking.

Fig. 45.18 Structure of the tongue

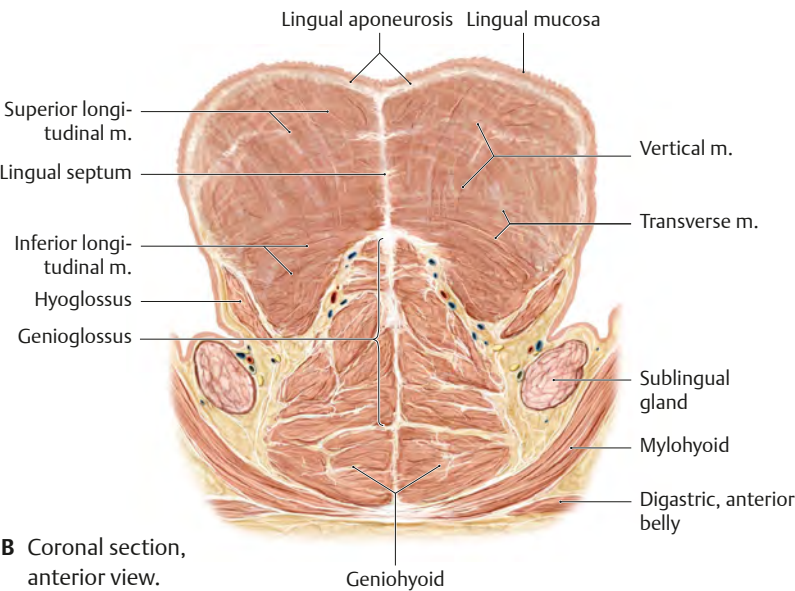
Superior view. The V-shaped sulcus terminalis divides the tongue into an anterior 2/3rds (oral, presulcal) and a posterior 1/3rd (pharyngeal, postsulcal).

Fig. 45.19 Muscles of the tongue

The extrinsic lingual muscles (genioglossus, hyoglossus, palatoglossus, and styloglossus) have bony attachments and move the tongue as a whole. The intrinsic lingual muscles (superior and inferior longitudinal muscles, transverse muscle, and vertical muscle) have no bony attachments and alter the shape of the tongue.



A Left lateral view.



B Coronal section, anterior view.

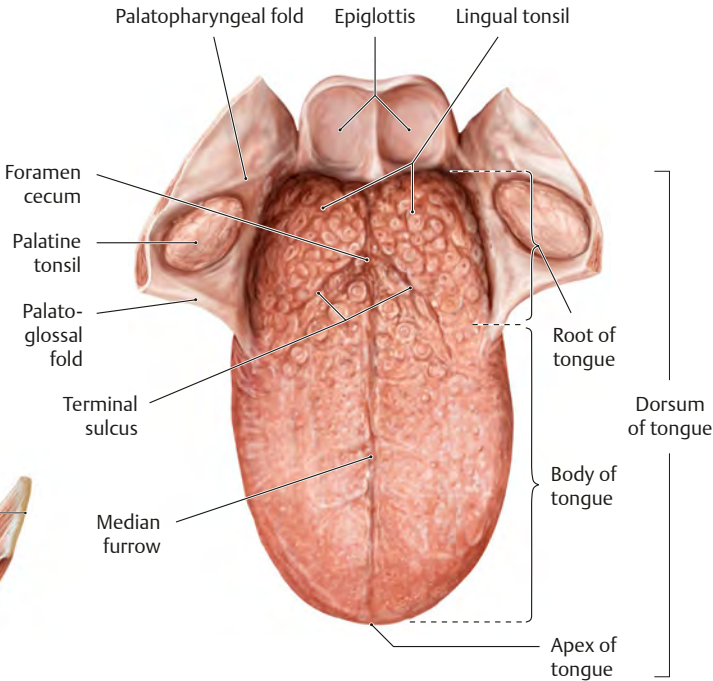


Fig. 45.20 Somatosensory and taste innervation of the tongue
Superior view.

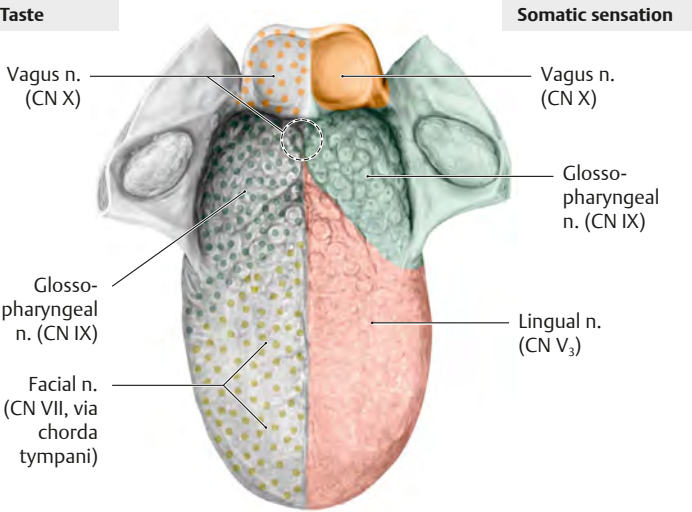


Fig. 45.21 Neurovasculature of the tongue

The lingual muscles receive somatomotor innervation from the hypoglossal nerve (CN XII), with the exception of the palatoglossus (supplied by the vagus nerve, CN X).

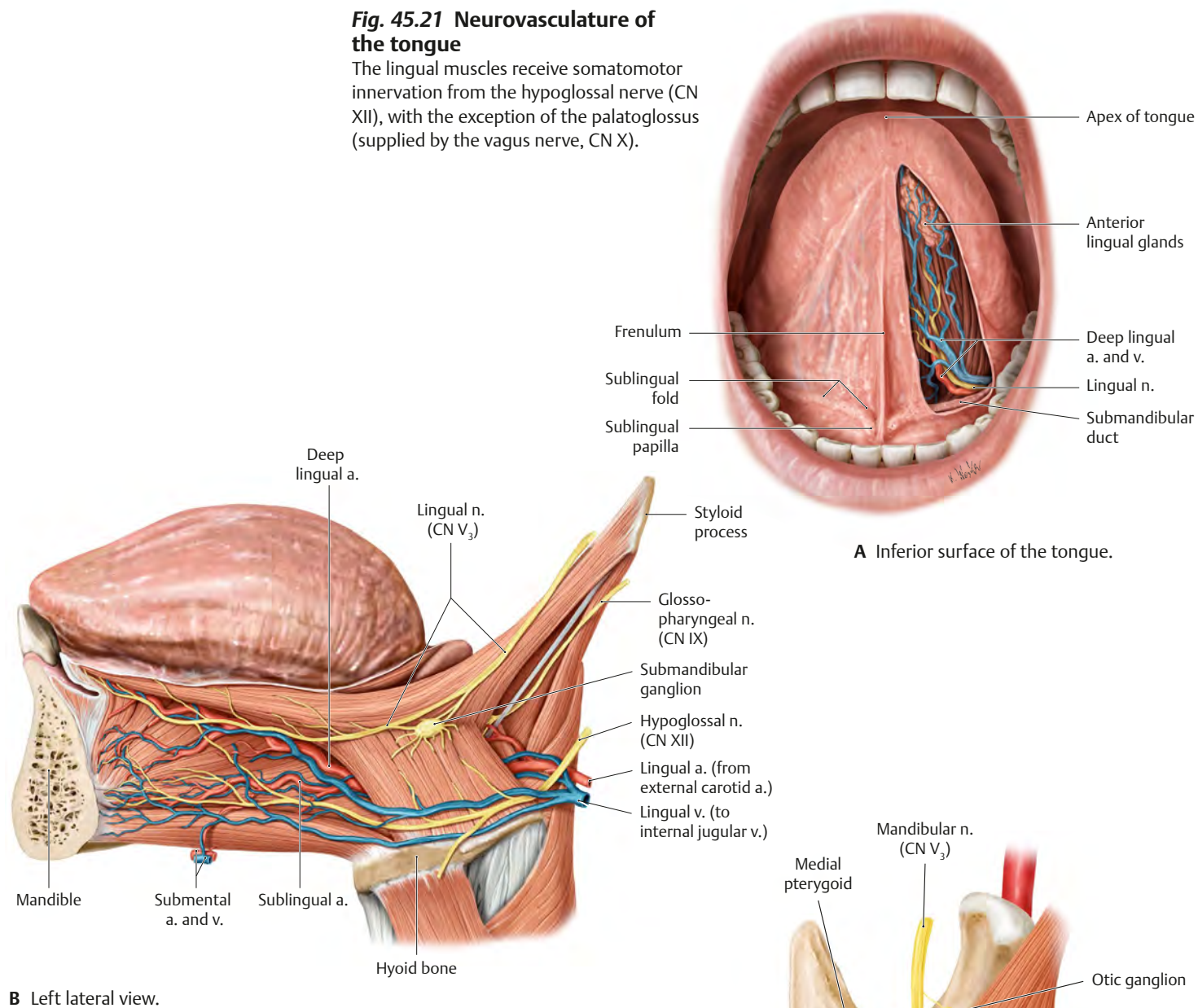
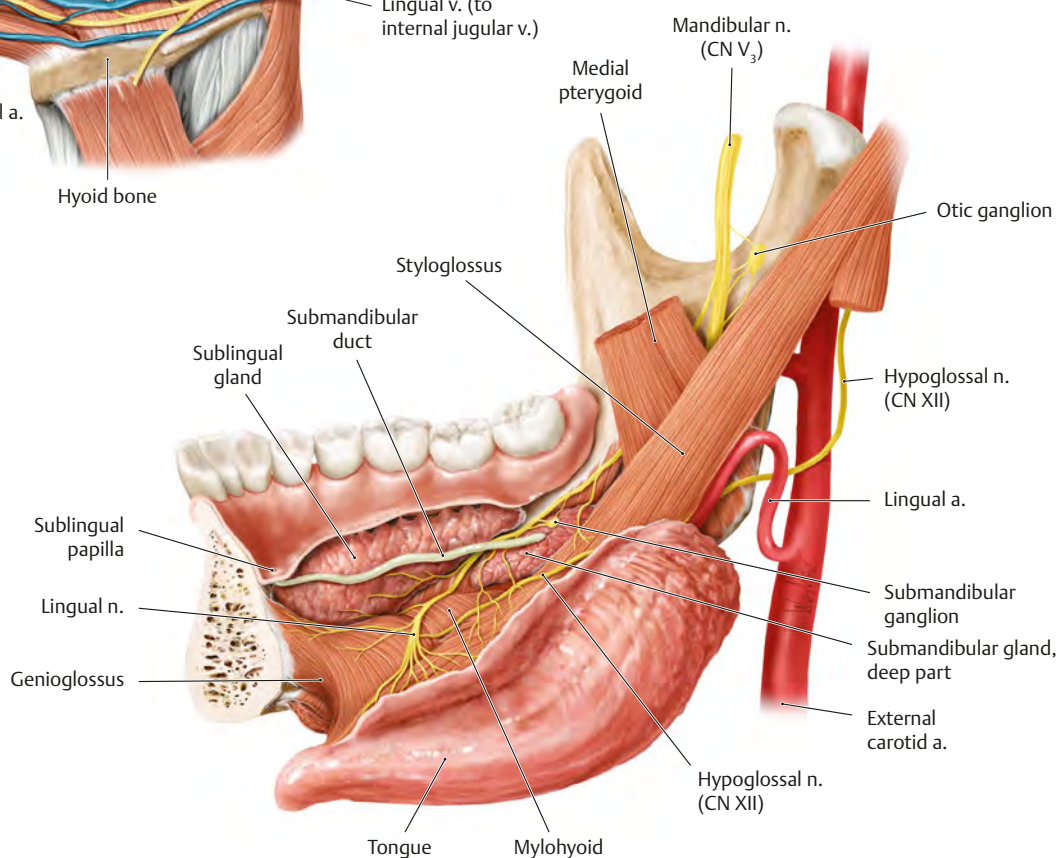


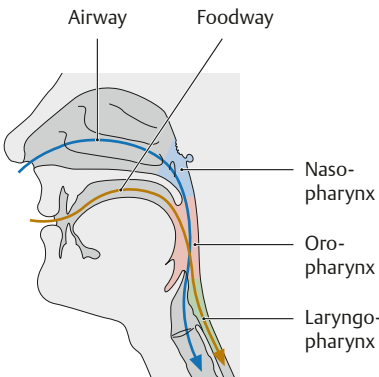
Fig. 45.22 Floor of mouth with tongue pulled from midline

Right mandible, medial view. The oral cavity is generally dissected on a hemisected head. To see the relationship of structures and the base of the tongue/floor of the mouth, the tongue is pulled out of the plane of the dissection and an incision is made in the mucosa of the region.



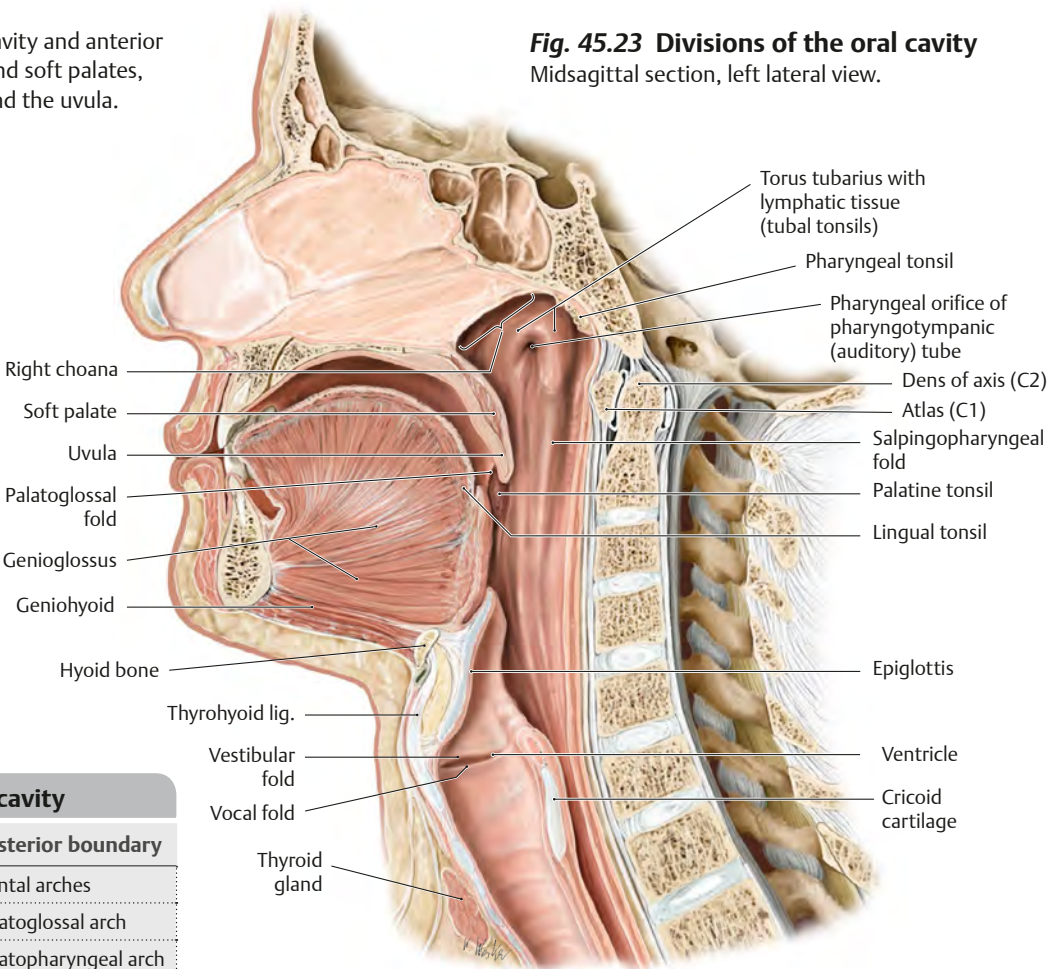
Topography of the Oral Cavity & Salivary Glands

The oral cavity is located below the nasal cavity and anterior to the pharynx. It is bounded by the hard and soft palates, the tongue and muscles of the oral floor, and the uvula.



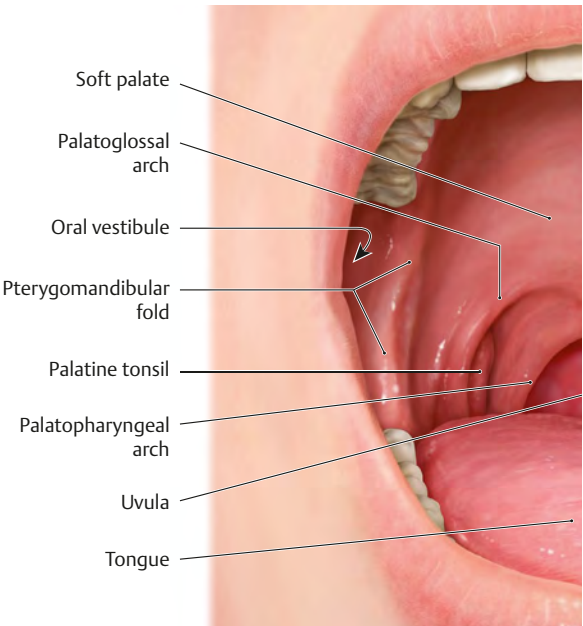
A Organization of the oral cavity.

Table 45.3 Divisions of the oral cavity		
Part	Anterior boundary	Posterior boundary
Oral vestibule	Lips/cheek	Dental arches
Oral cavity proper	Dental arches	Palatoglossal arch
Fauces (throat)	Palatoglossal arch	Palatopharyngeal arch

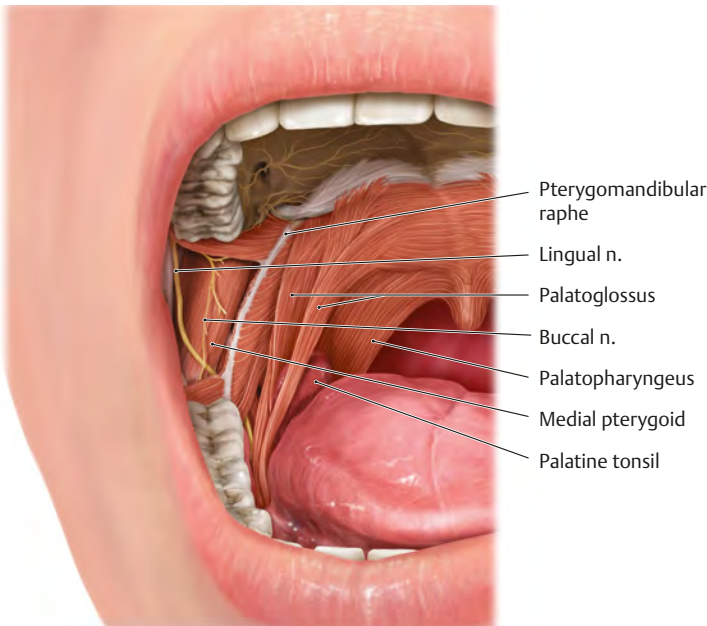


B Boundaries of the oral cavity.

Fig. 45.24 Oral cavity topography
Right side, anterior view.



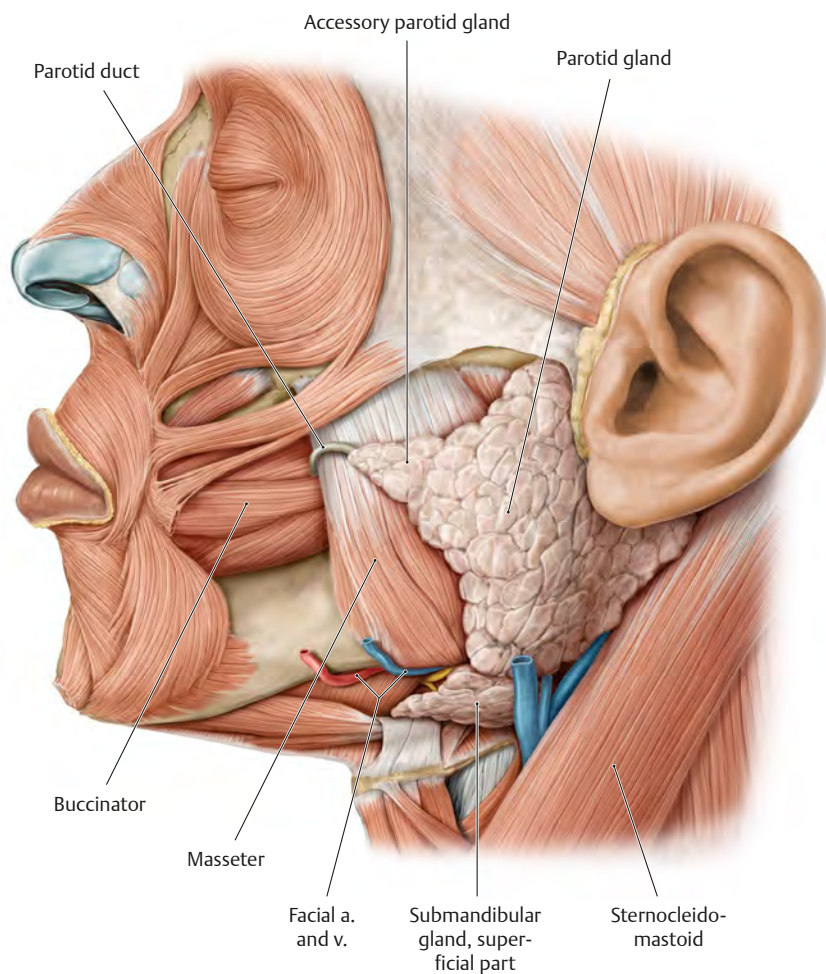
A Open oral cavity.



B Oral cavity with mucosa removed from the roof and walls.

The three large, paired salivary glands are the parotid, submandibular, and sublingual glands. The parotid gland is a purely serous (watery)

salivary gland. The sublingual gland is predominantly mucous; the submandibular gland is a mixed seromucous gland.



A Parotid gland, left lateral view. *Note:* The parotid duct penetrates the buccinator muscle to open opposite the second upper molar.

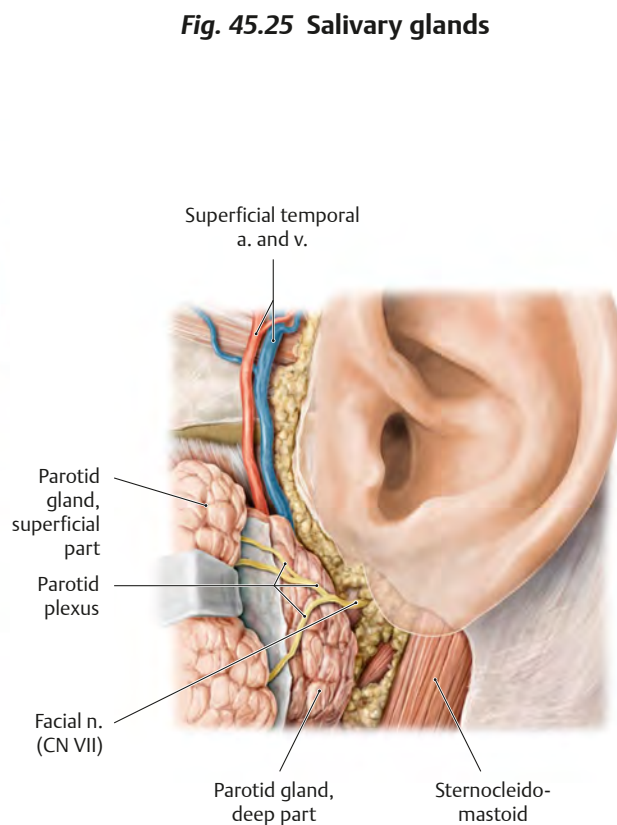
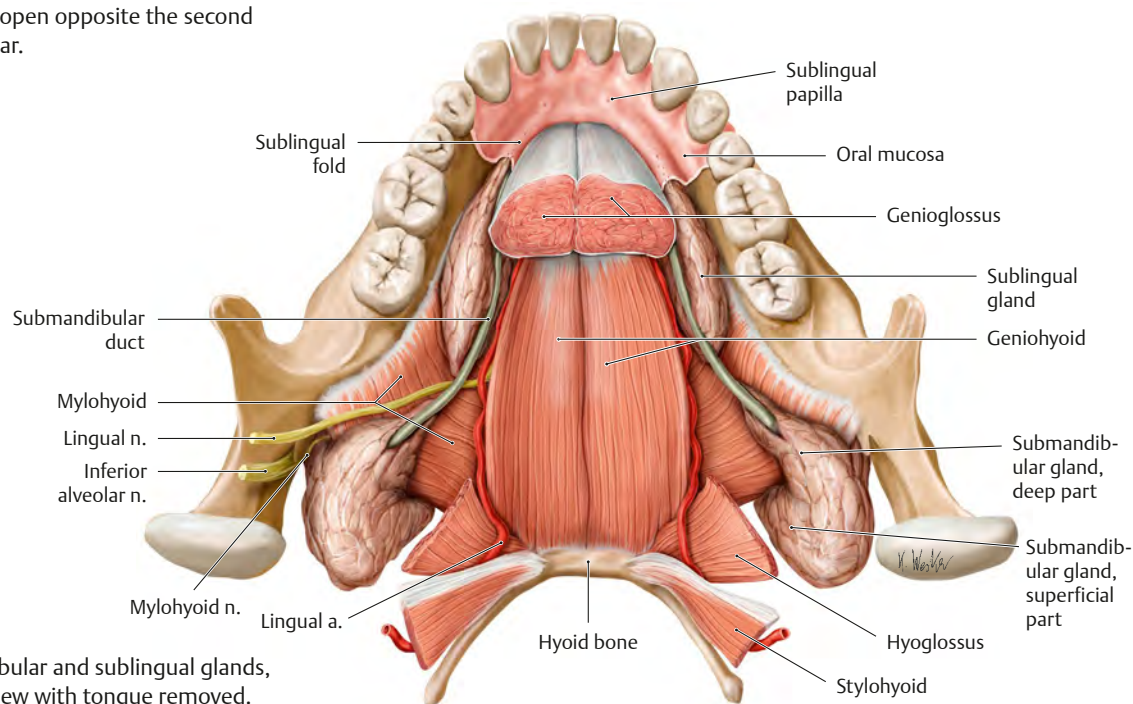


Fig. 45.25 Salivary glands

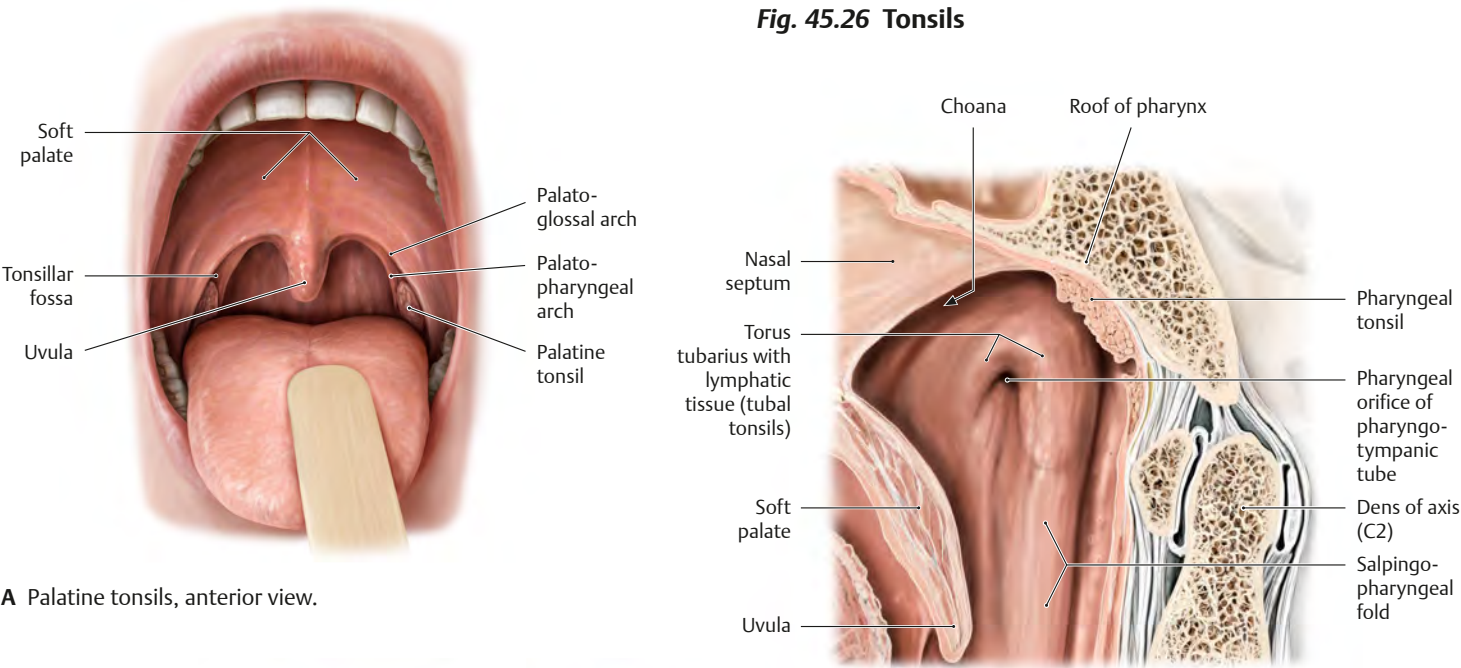
B Facial nerve in the parotid gland, left lateral view. The branching of the facial nerve into the parotid plexus (see p. 568) separates the parotid gland into a superficial part and a deep part.



C Submandibular and sublingual glands, superior view with tongue removed.

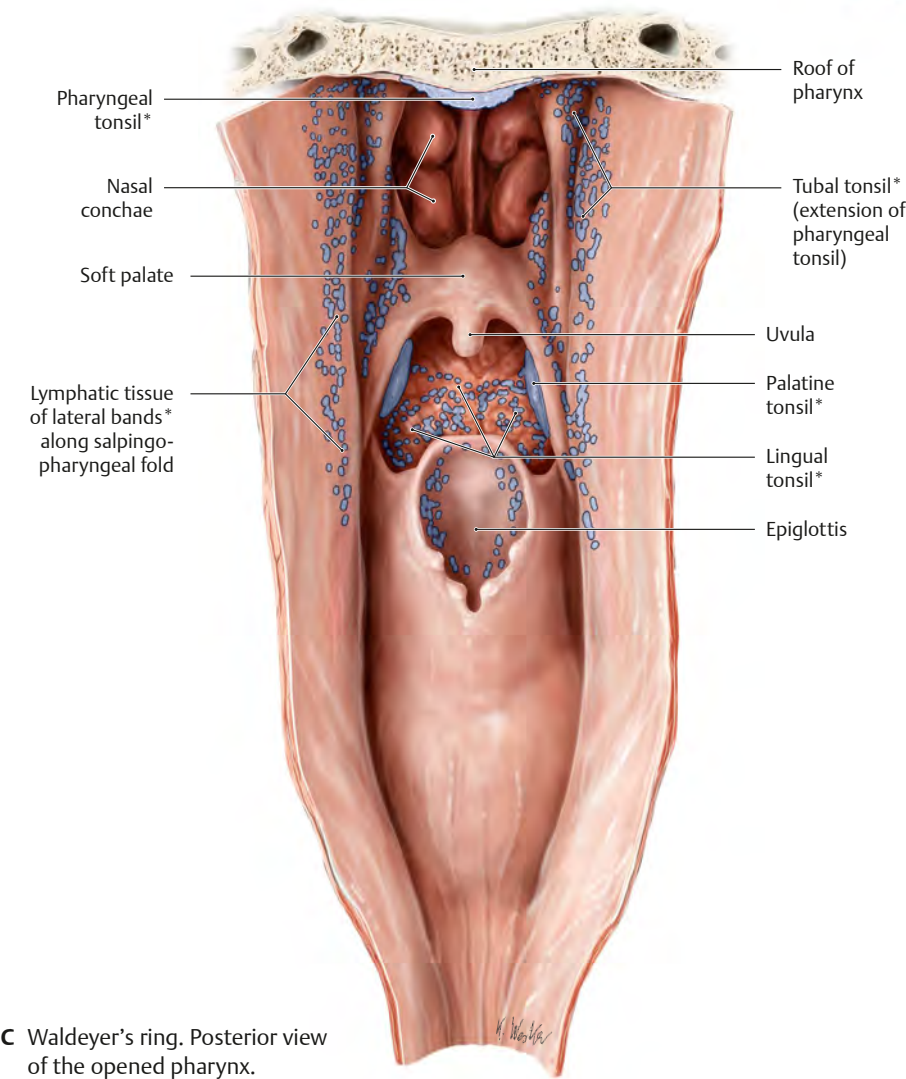
Tonsils & Pharynx

Fig. 45.26 Tonsils



A Palatine tonsils, anterior view.

B Pharyngeal tonsils. Sagittal section through the roof of the pharynx.



C Waldeyer's ring. Posterior view of the opened pharynx.

Table 45.4 Structures in Waldeyer's ring	
Tonsil*	#
Pharyngeal tonsil	1
Tubal tonsils	2
Palatine tonsils	2
Lingual tonsil	1
Lateral bands	2

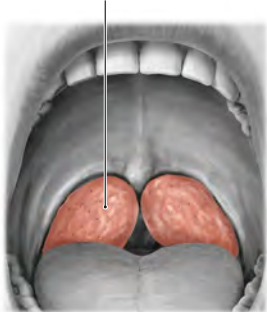


Clinical box 45.2

Tonsil infections

Abnormal enlargement of the palatine tonsils due to severe viral or bacterial infection can result in obstruction of the oropharynx, causing difficulty swallowing.

Enlarged palatine tonsil



Particularly well developed in young children, the pharyngeal tonsil begins to regress at 6 to 7 years of age. Abnormal enlargement is common, with the tonsil bulging into the nasopharynx and obstructing air passages, forcing the child to "mouth breathe."

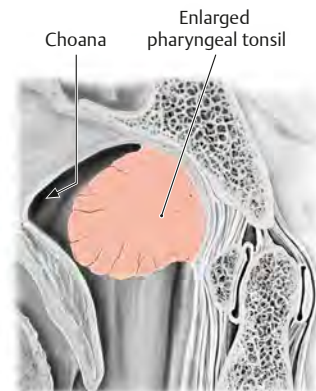
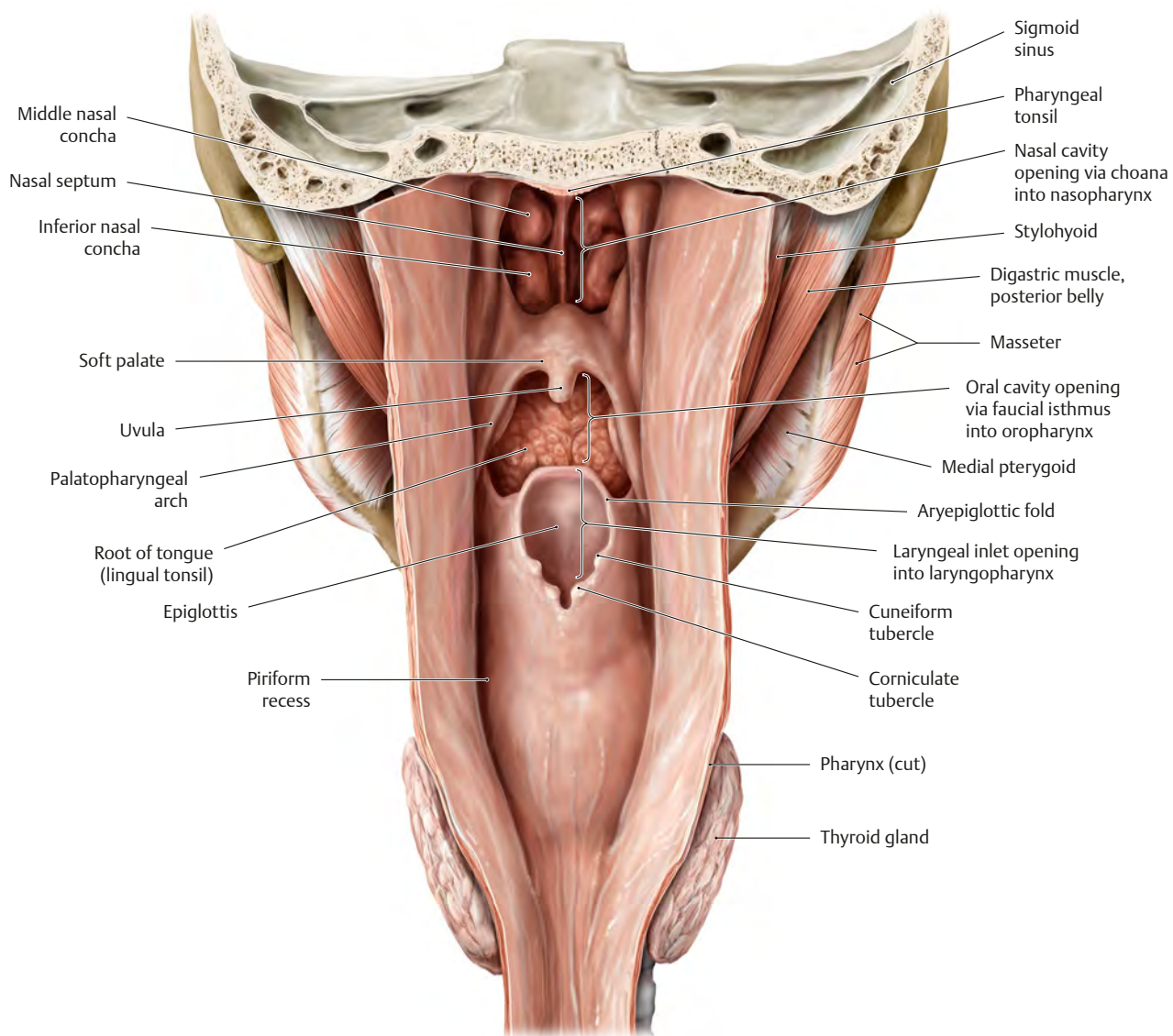


Fig. 45.27 Pharyngeal mucosa

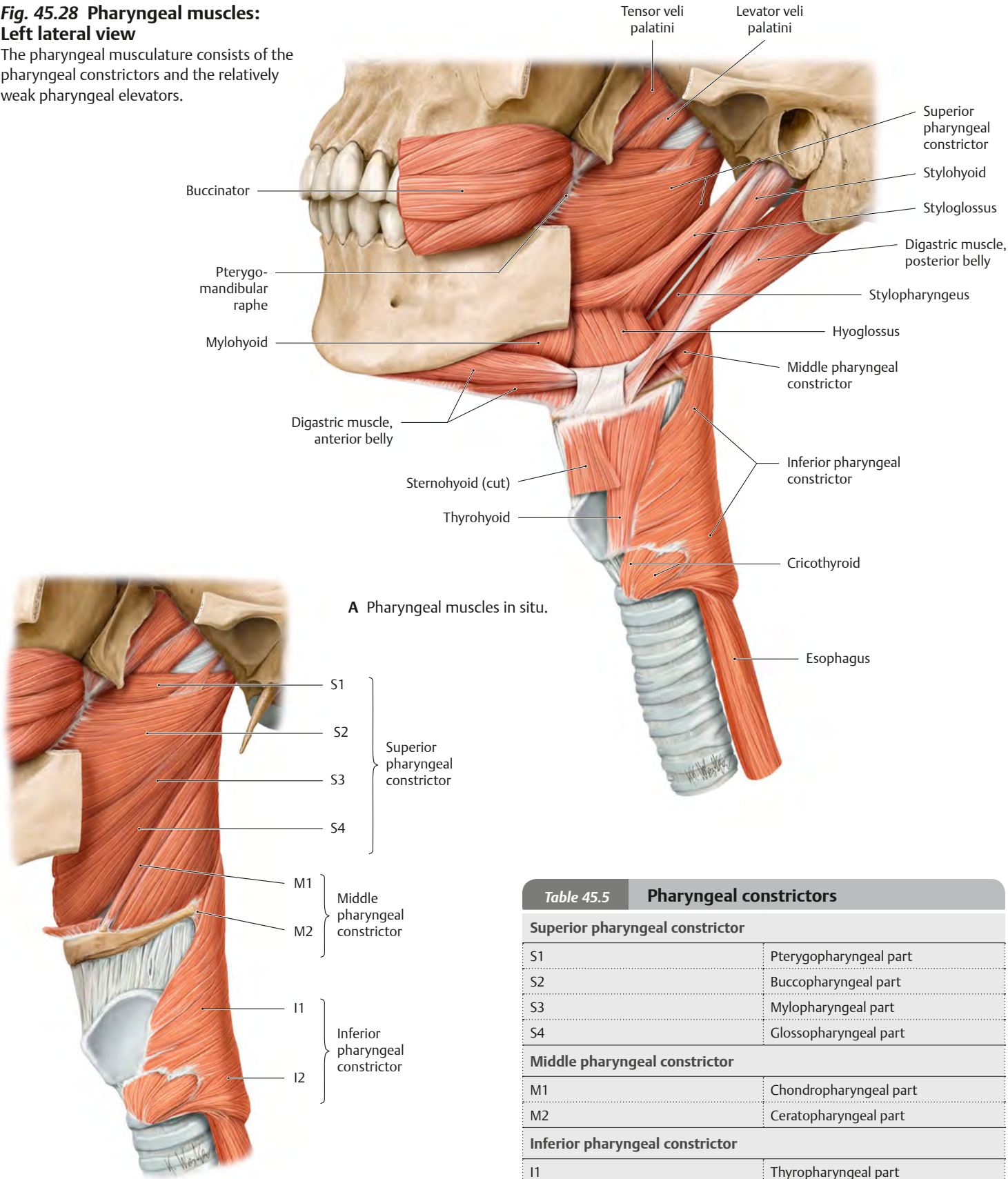
Posterior view of the opened pharynx. The anterior portion of the muscular tube contains three openings: choanae (to the nasal cavity), faucial isthmus (to the oral cavity), and aditus (to the laryngeal inlet).



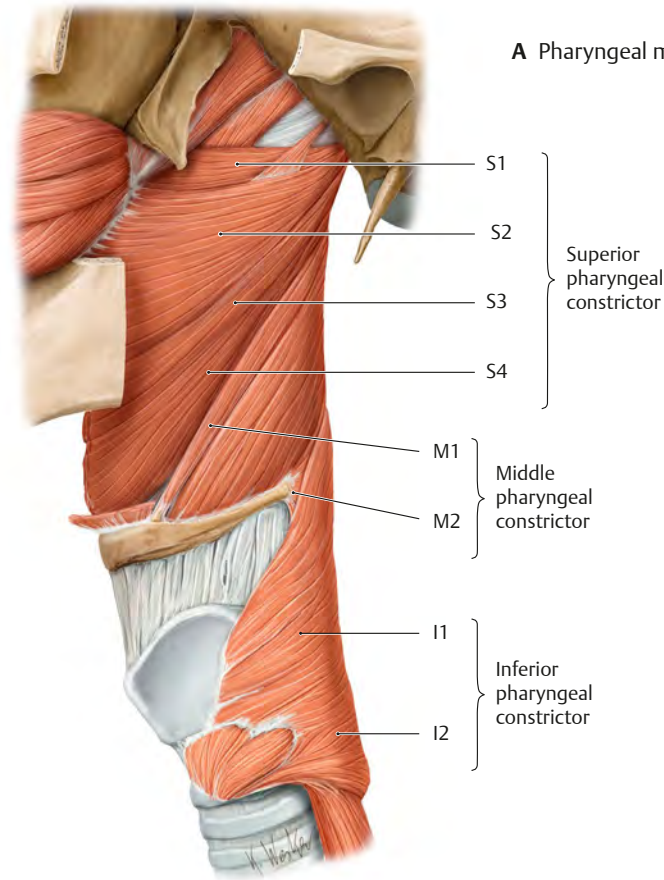
Pharyngeal Muscles

Fig. 45.28 Pharyngeal muscles: Left lateral view

The pharyngeal musculature consists of the pharyngeal constrictors and the relatively weak pharyngeal elevators.

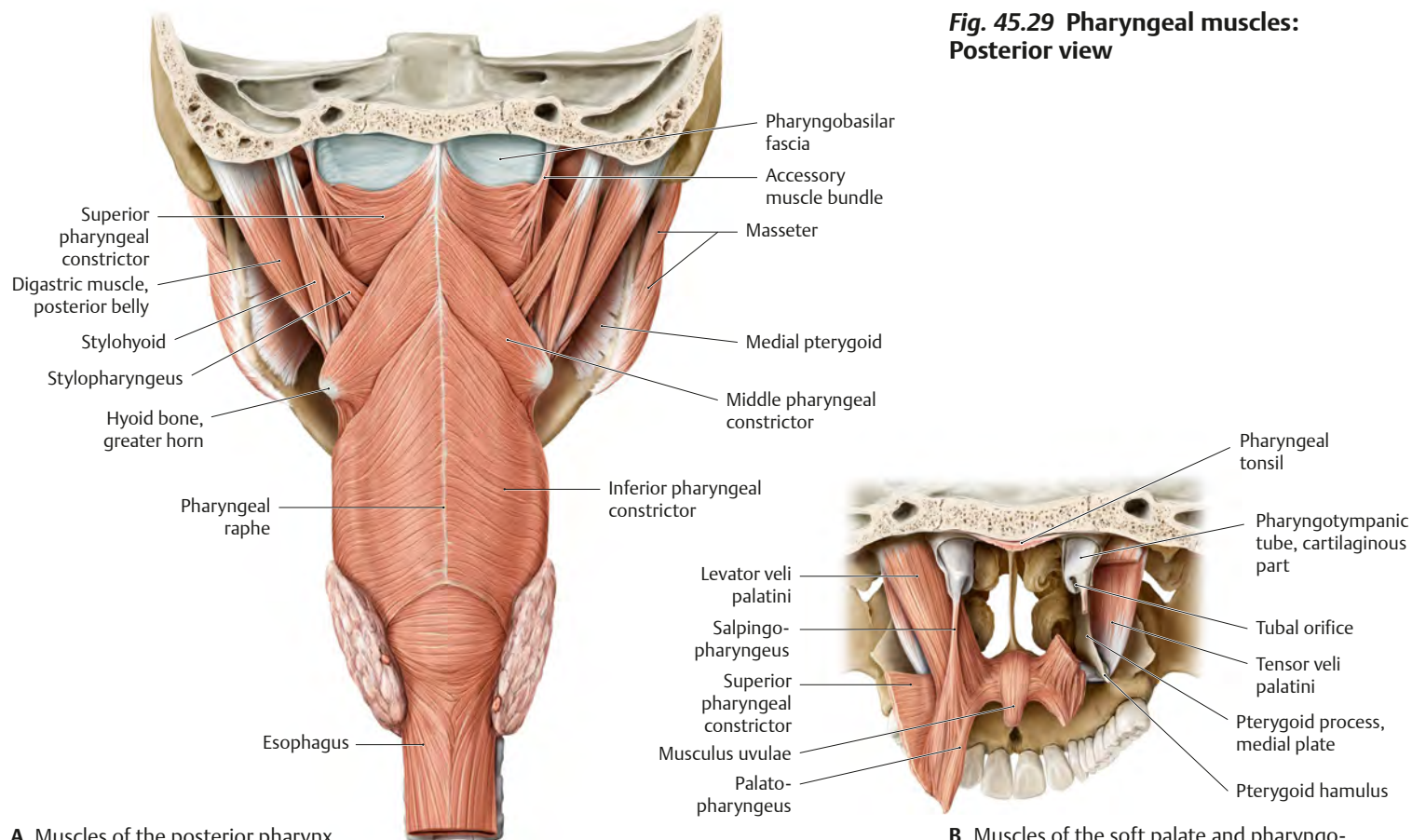
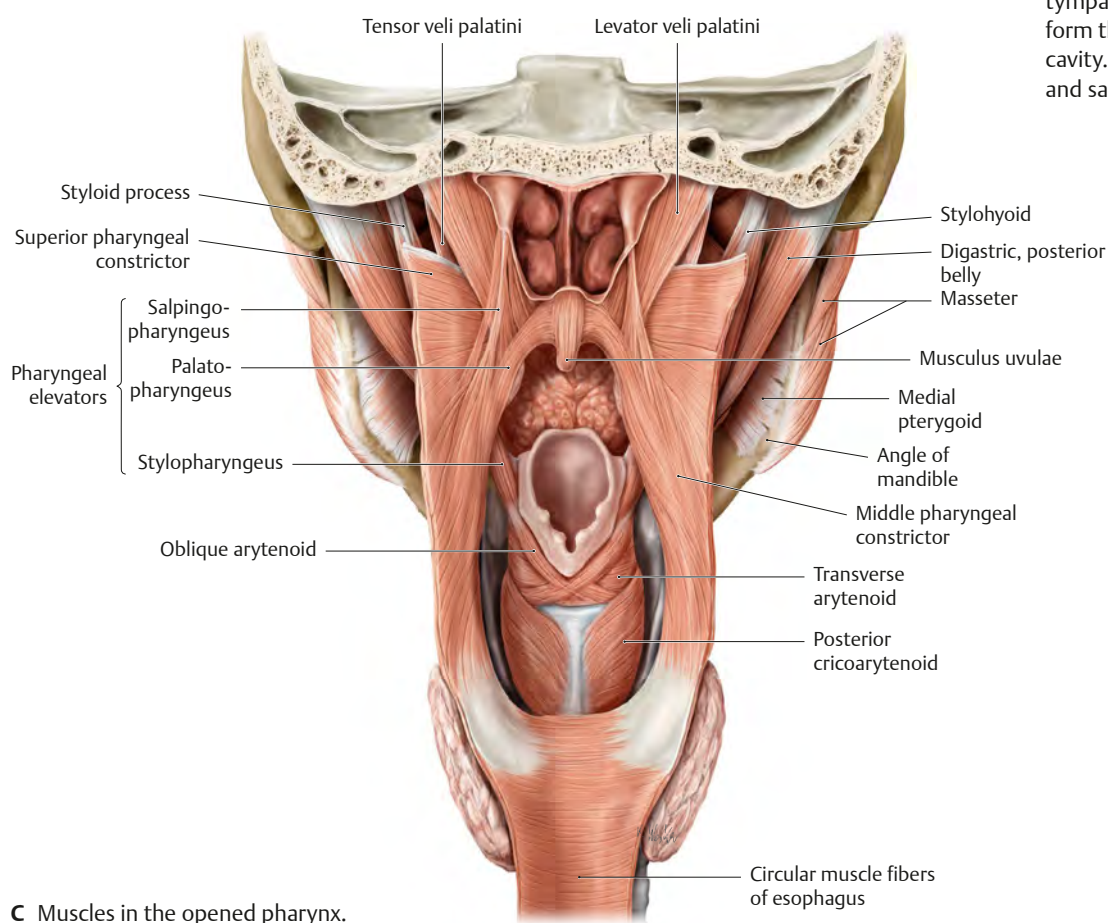


A Pharyngeal muscles in situ.



B Subdivisions of the pharyngeal constrictors.

Table 45.5 Pharyngeal constrictors	
Superior pharyngeal constrictor	
S1	Pterygopharyngeal part
S2	Buccopharyngeal part
S3	Mylopharyngeal part
S4	Glossopharyngeal part
Middle pharyngeal constrictor	
M1	Chondropharyngeal part
M2	Ceratopharyngeal part
Inferior pharyngeal constrictor	
I1	Thyropharyngeal part
I2	Cricopharyngeal part

Fig. 45.29 Pharyngeal muscles: Posterior view**A** Muscles of the posterior pharynx.**B** Muscles of the soft palate and pharyngotympanic tube. The muscles of the fauces form the posterior boundary of the oral cavity. *Cut on right side:* Levator veli palatini and salpingopharyngeus.**C** Muscles in the opened pharynx.

Neurovasculature of the Pharynx

Fig. 45.30 Neurovasculature in the parapharyngeal space
 Posterior view. *Removed:* Vertebral column and posterior structures.

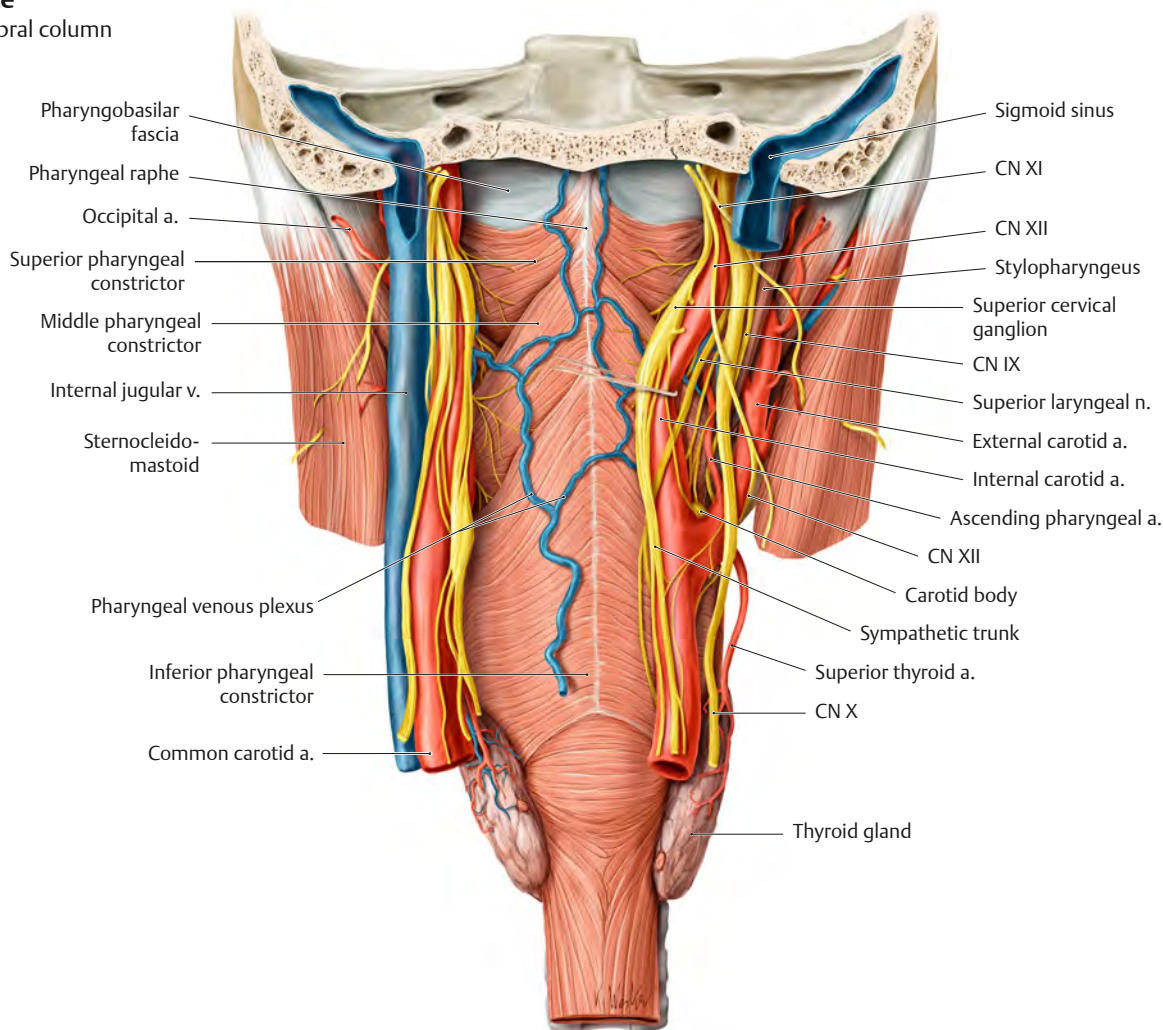


Fig. 45.31 Fasciae and potential tissue spaces in the head
 Transverse section at the level of the tonsillar fossa, superior view. Fascial boundaries are key to outlining pathways for the spread of infection. Potential spaces in the head, shown on this figure, become true spaces when they are infiltrated by products of infection. These spaces are defined by bones, muscles and fascia and initially confine an infection but eventually allow it to spread through communications between spaces.

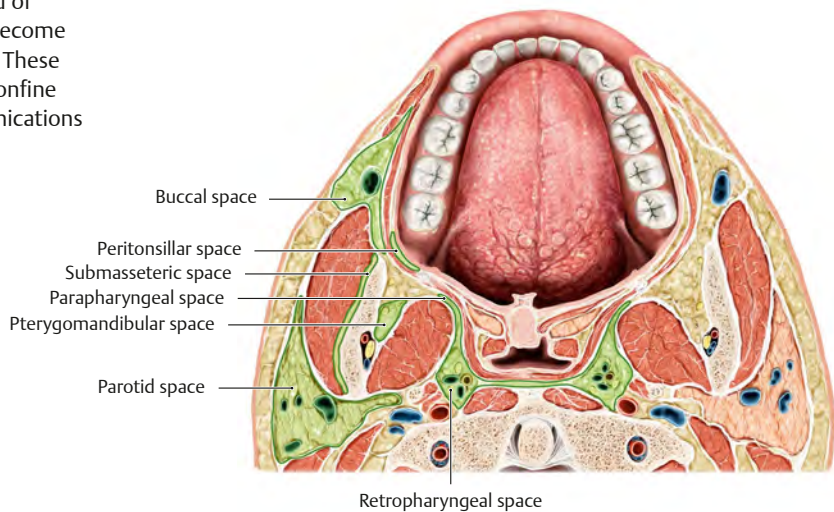
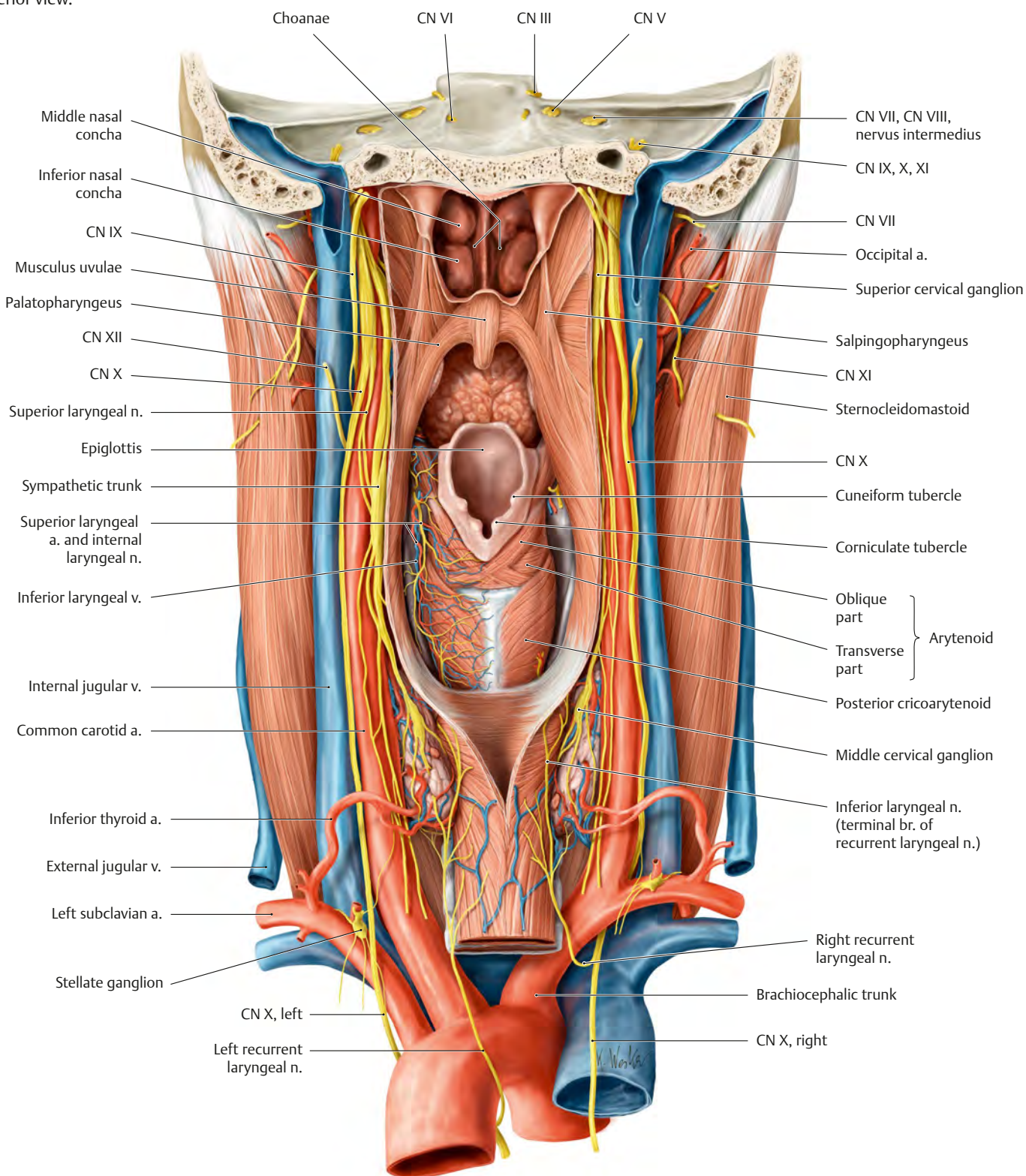


Fig. 45.32 Neurovasculature of the opened pharynx
Posterior view.



CN III, oculomotor n.; CN V, trigeminal n.; CN VI, abducent n.;
CN VII, facial n.; CN VIII, vestibulocochlear n.; CN IX, glossopharyngeal n.;
CN X, vagus n.; CN XI, accessory n.; CN XII, hypoglossal n..
See Chapter 39 for the cranial nerves.

46 Sectional & Radiographic Anatomy

Sectional Anatomy of the Head & Neck (I)

Fig. 46.1 Coronal section through the anterior orbital margin

Anterior view. This section shows four regions of the head: the oral cavity, the nasal cavity and sinuses, the orbit, and the anterior cranial fossa. Muscles of the oral floor, the apex of the tongue, the hard palate, the neurovascular structures in the mandibular canal, and the first molar are all seen in the region of the oral cavity. This section reinforces the clinical implications of the relationship of the maxillary sinus with the

maxillary teeth and the floor of the orbit and with the maxillary nerve in the infraorbital groove. The medial wall of the orbit shares a thin bony wall (orbital plate) with the ethmoid air cells (sinus). The section is enough anterior so that the lateral bony walls of the orbit are not included due to the lateral curvature of the skull.

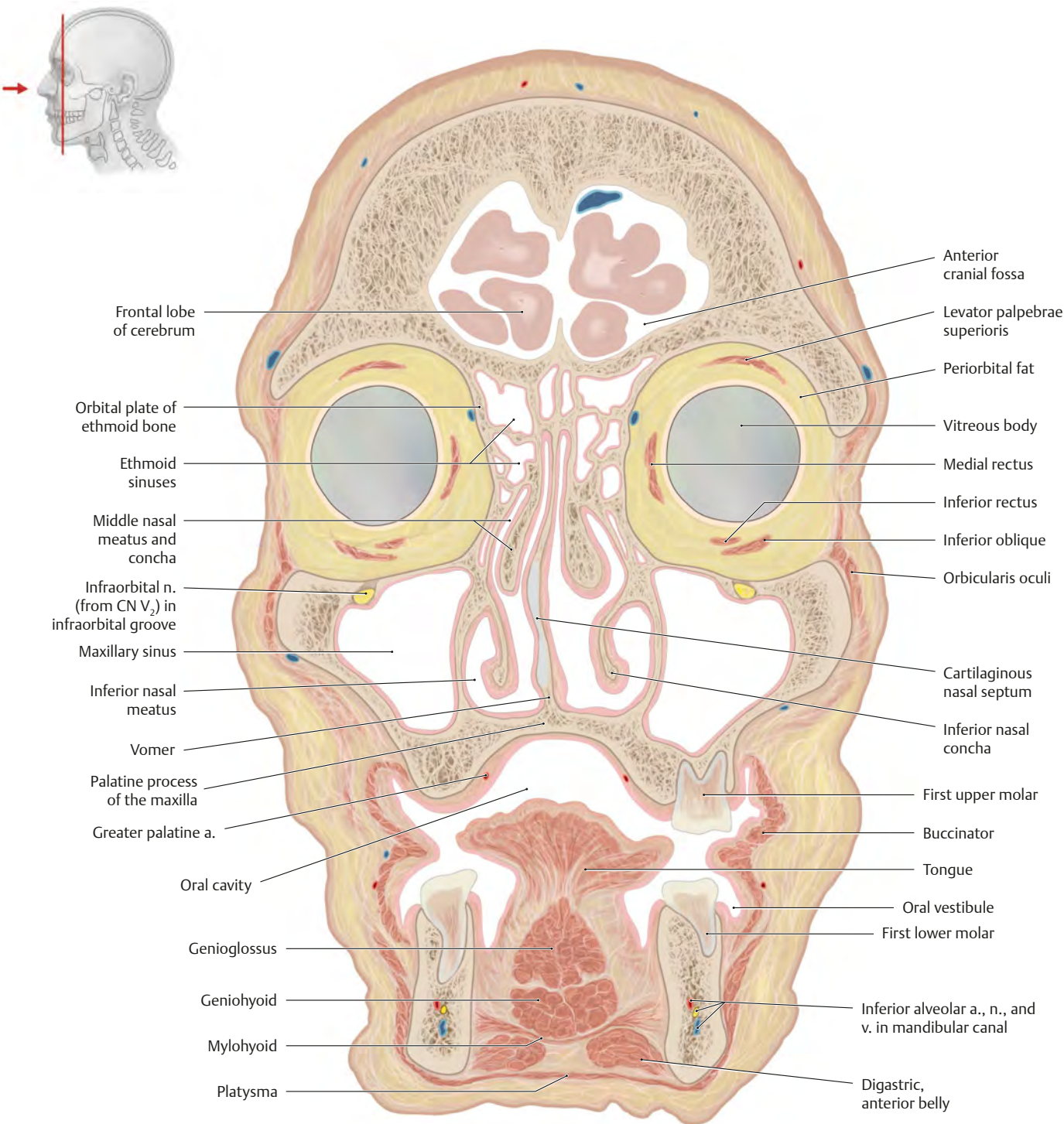


Fig. 46.2 Coronal section through the orbital apex

Anterior view. In this more posterior section than that of Fig. 46.1, the soft palate now separates the oral and nasal cavities. The buccal fat pad is also visible. The section is slightly angled, producing an apparent discontinuity in the mandibular ramus on the left side.

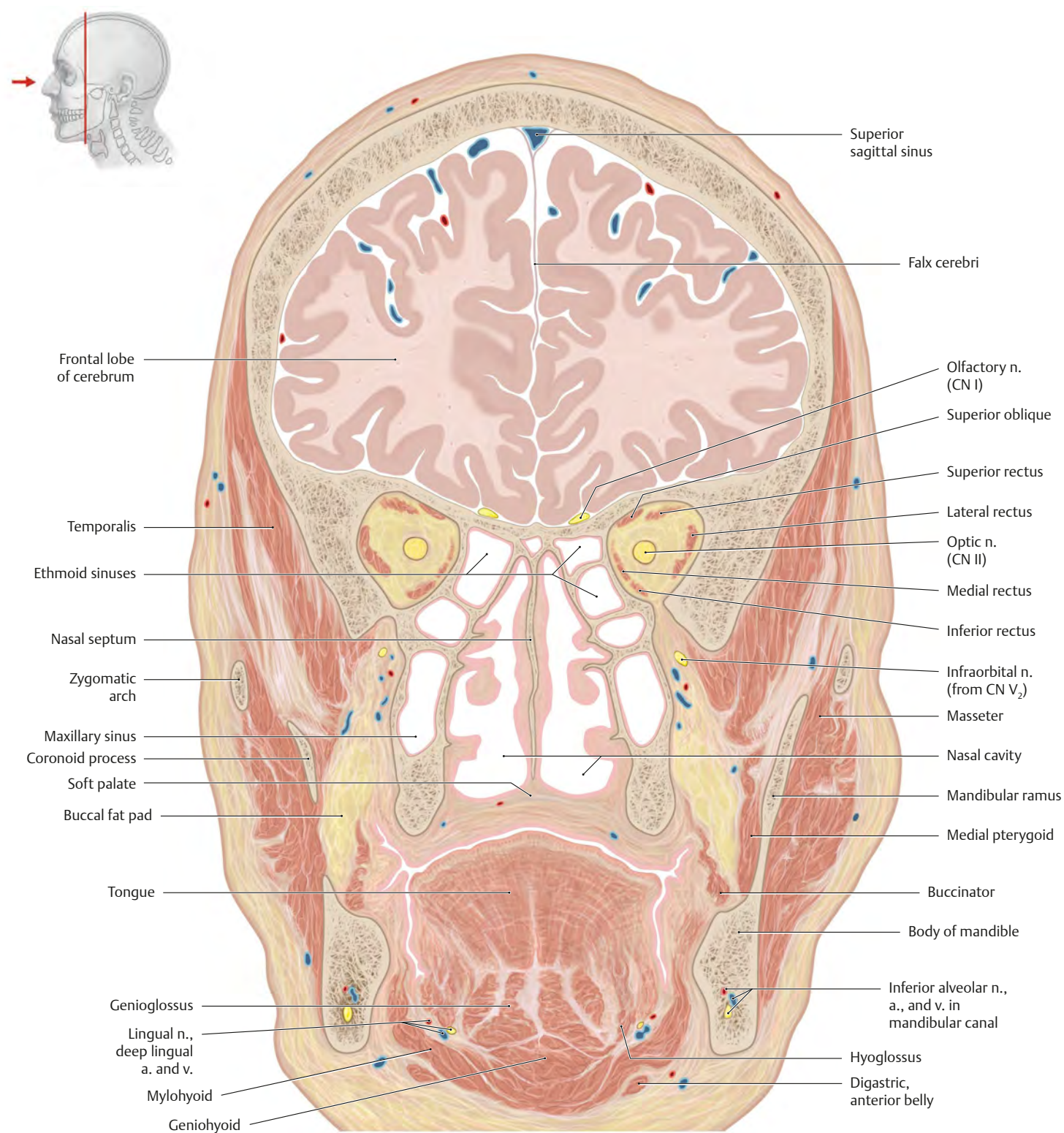


Fig. 46.3 Coronal section through the pituitary
Anterior view.

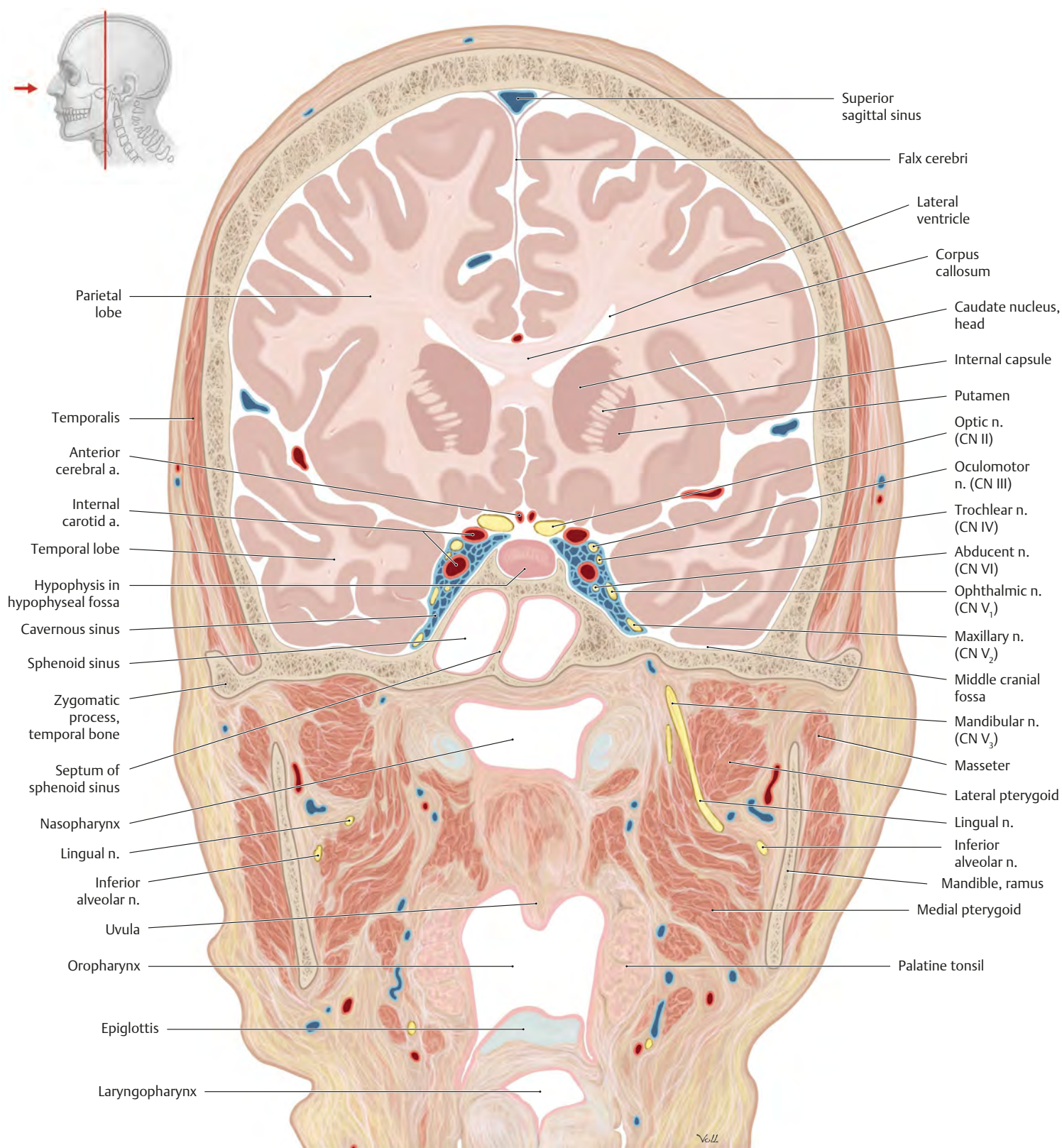


Fig. 46.4 Midsagittal section through the nasal septum
Left lateral view.

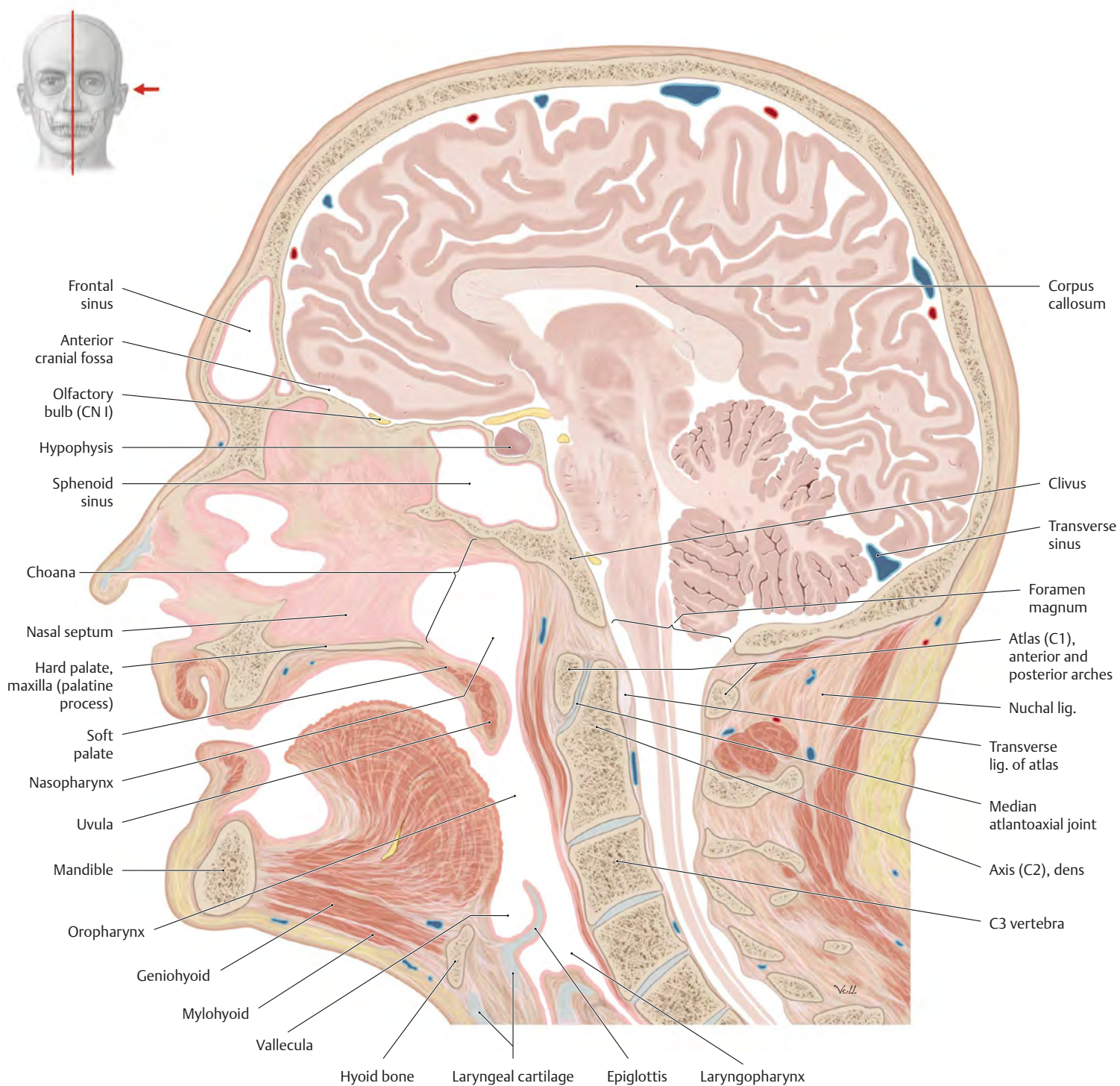


Fig. 46.5 Sagittal section through the medial orbital wall

Left lateral view. This section passes through the inferior and middle conchae of the lateral nasal wall. Three of the four paranasal air sinuses (ethmoid, sphenoid, and frontal) are seen in this section and in relation to the nasal cavity into which they drain. In the region of the cervical

spine, the vertebral artery is cut at multiple levels. The spinal nerves have been cut just prior to their lateral exit through the intervertebral foramina.

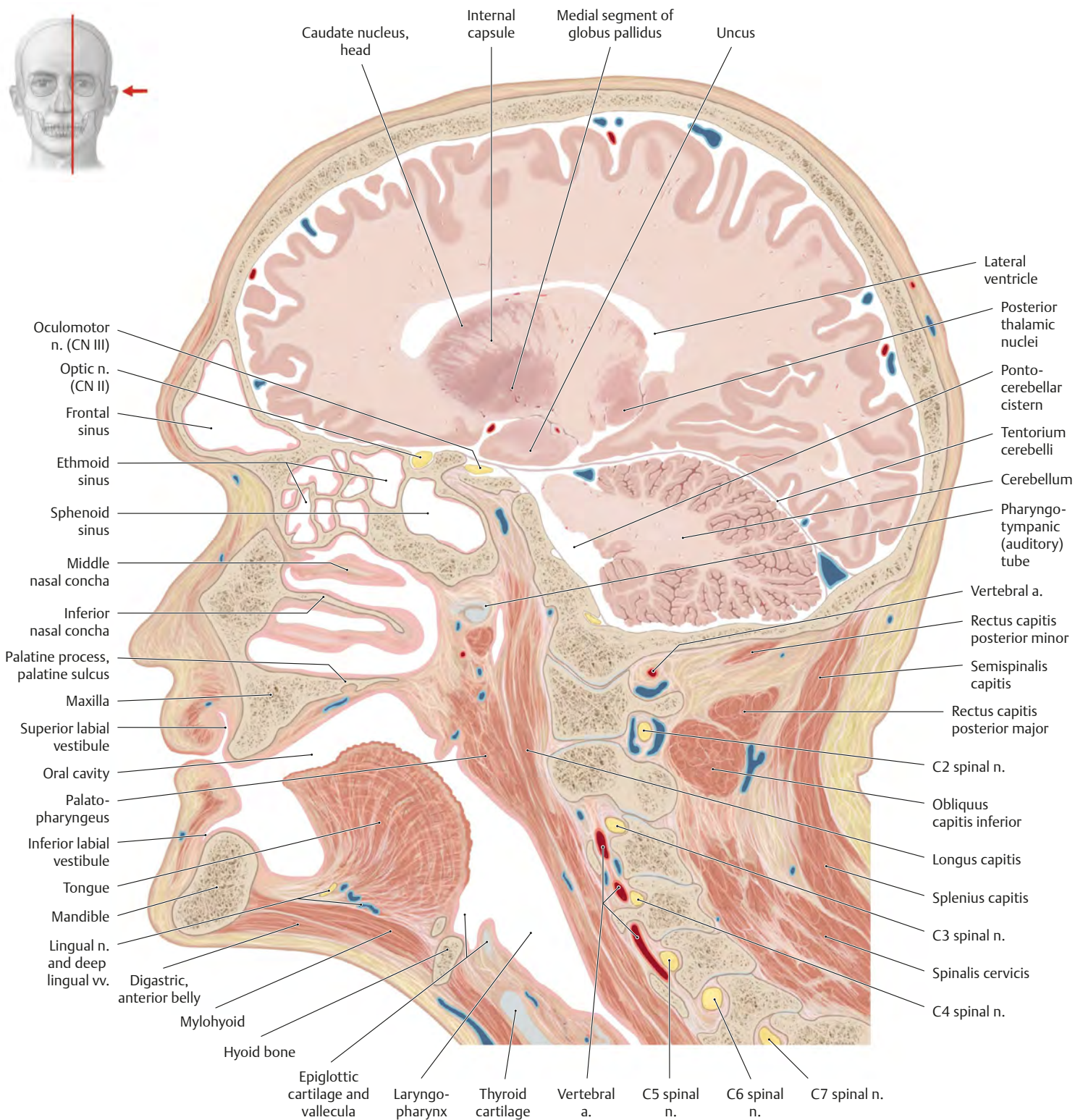


Fig. 46.6 Sagittal section through the inner third of the orbit

Left lateral view. This section passes through the maxillary, frontal, and sphenoid sinuses and a single ethmoidal air cell. The pharyngeal and masticatory muscles are revealed grouped around the cartilaginous

part of the pharyngotympanic (auditory) tube. The palatine tonsil of the oral cavity and medial portion of the submandibular gland below the floor of the mouth are also seen in this section.

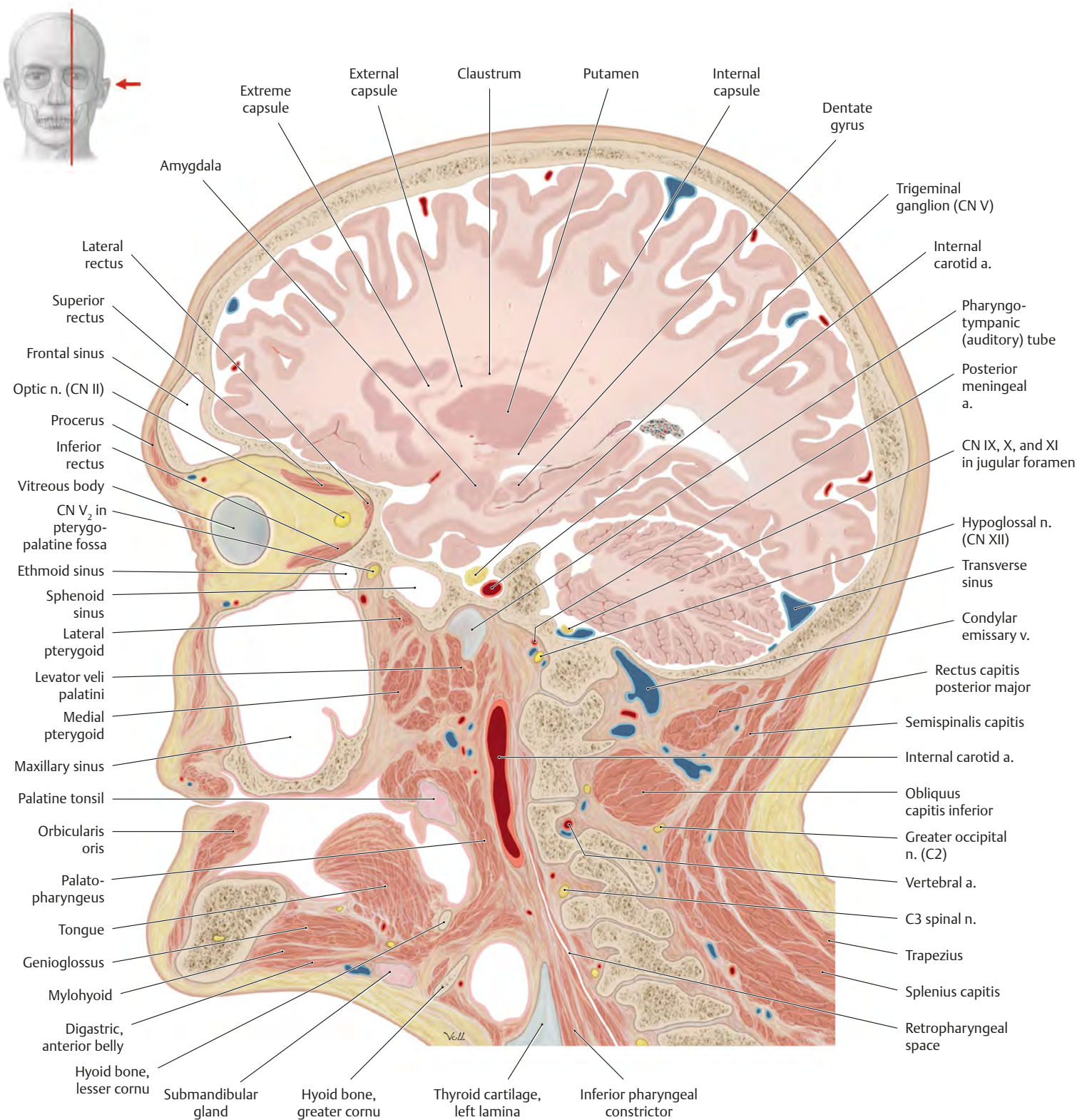


Fig. 46.7 Transverse section through the optic nerve and pituitary
Inferior view.

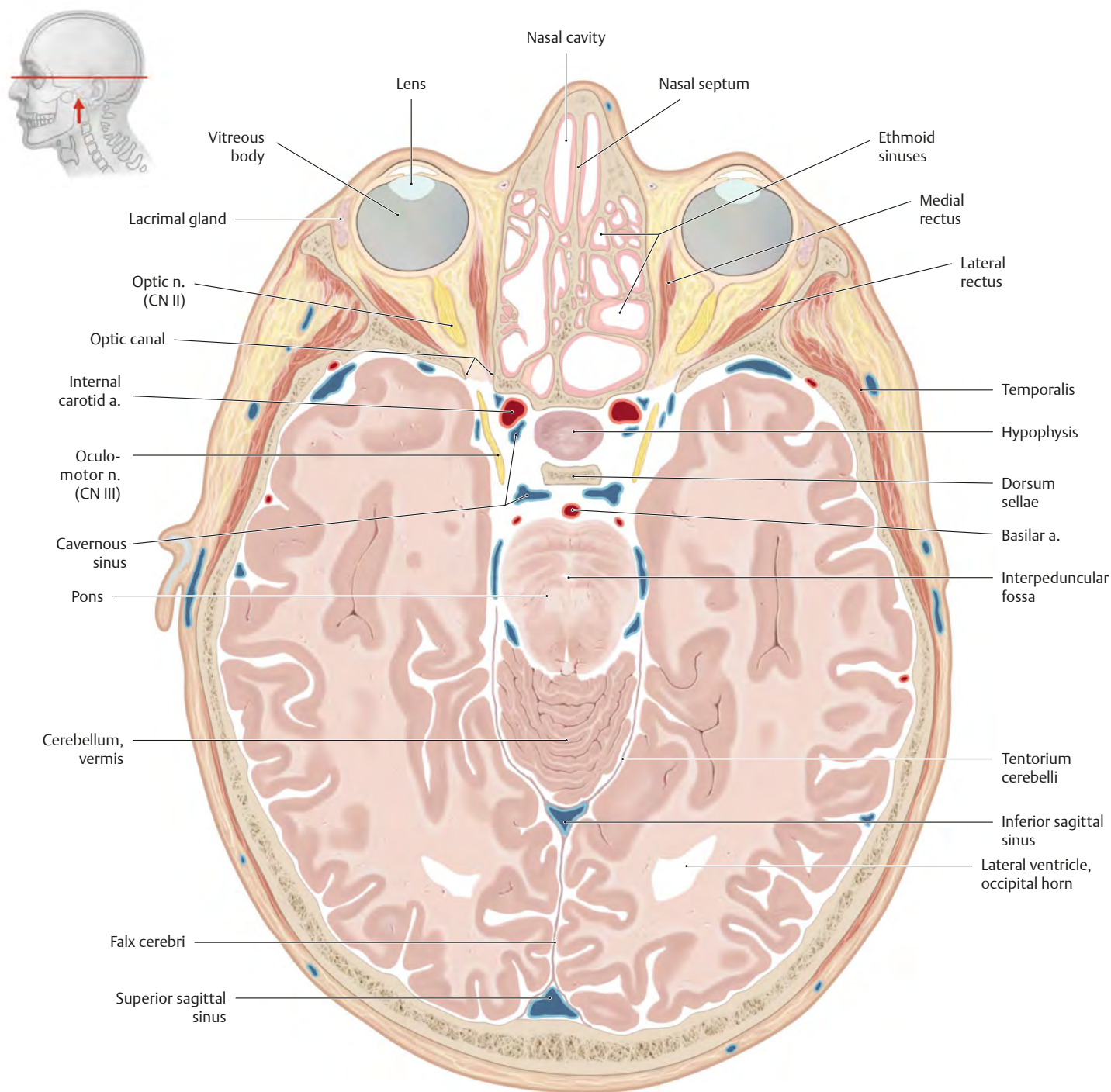
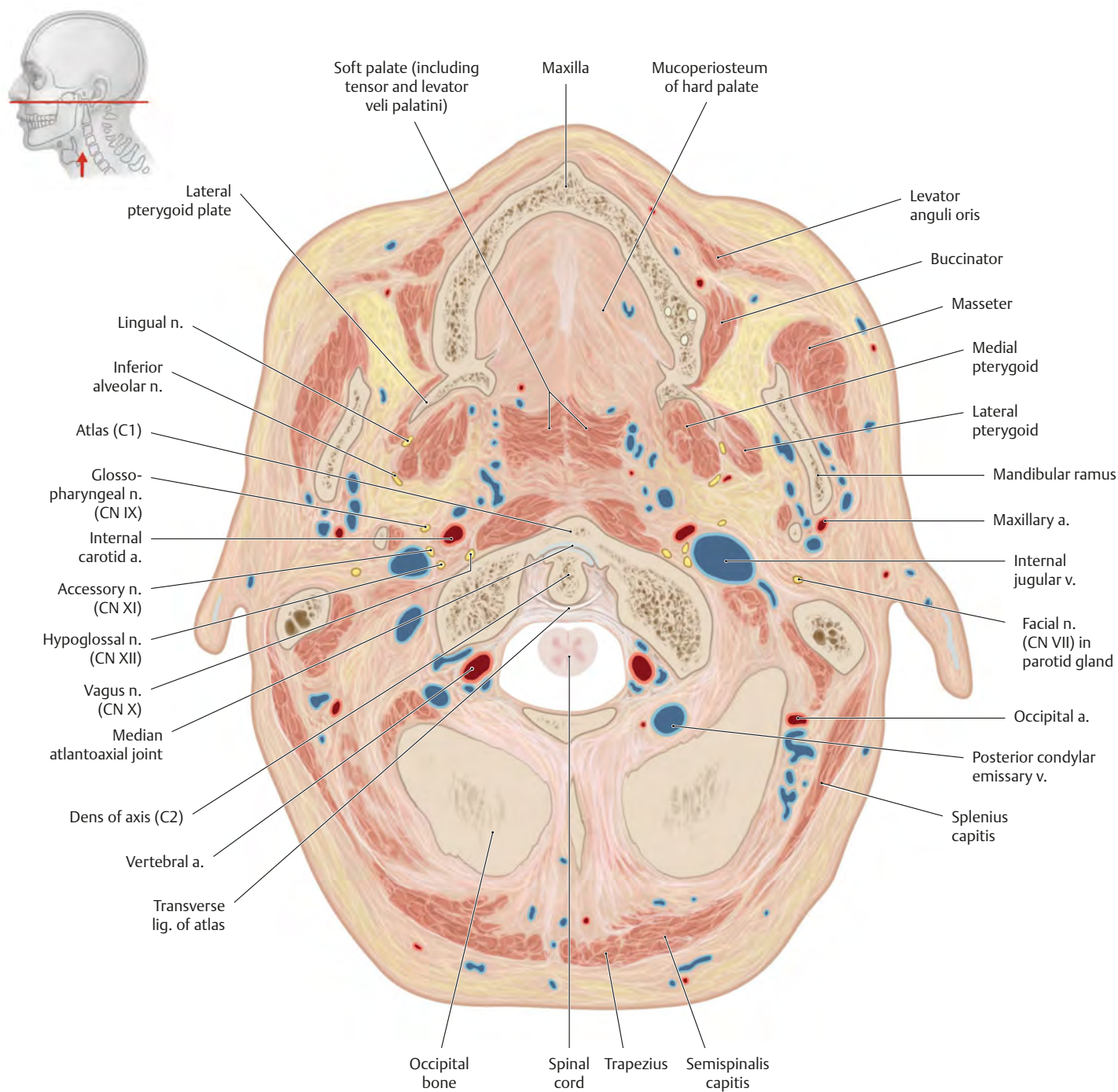


Fig. 46.8 Transverse section of head through the median atlantoaxial joint

Superior view. This section passes through the soft palate and mucoperiosteum of the hard palate. The articulation of the odontoid process (dens of C2) with the axis (C1) at the median atlantoaxial joint is shown, as well as the carotid sheath, containing the vertebral neuro-

vascular elements of the neck. The vertebral artery is sectioned as it prepares to enter the foramen magnum and fuse with its opposite to form the basilar artery.



Sectional Anatomy of the Head & Neck (V)

Fig. 46.9 Transverse section of the neck

Transverse section at the level of the C5 vertebral body. Inferior view. The internal and external jugular veins are separated by the sternocleidomastoid. The accessory nerve (CN XI) is just medial to this muscle as

it prepares to innervate it from behind. The elongated spinous process of the C7 vertebra (vertebra prominens) is also visible in the section due to the lordotic curvature of the neck.

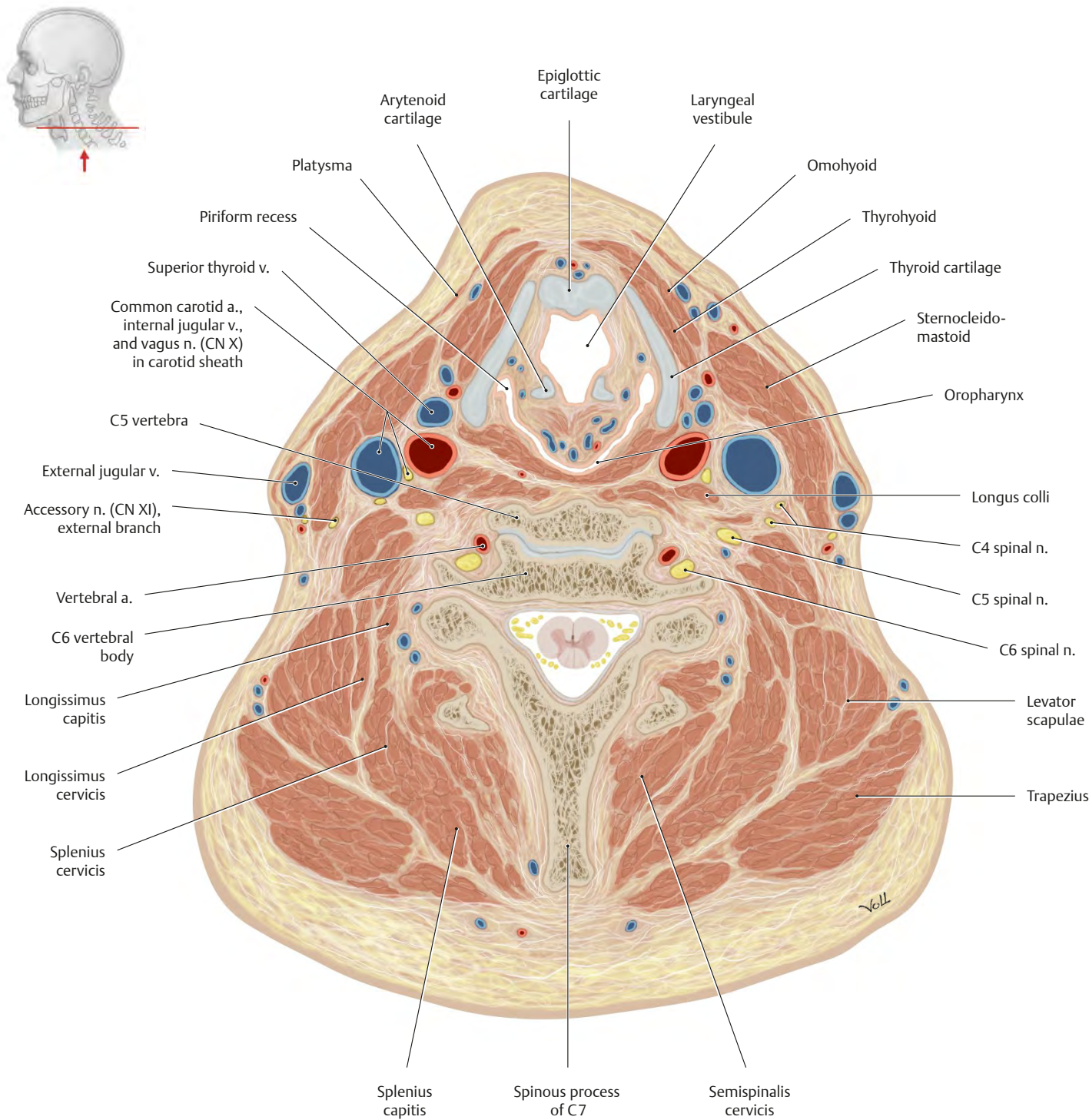


Fig. 46.10 Transverse section at the level of the C6 vertebral body
Inferior view.

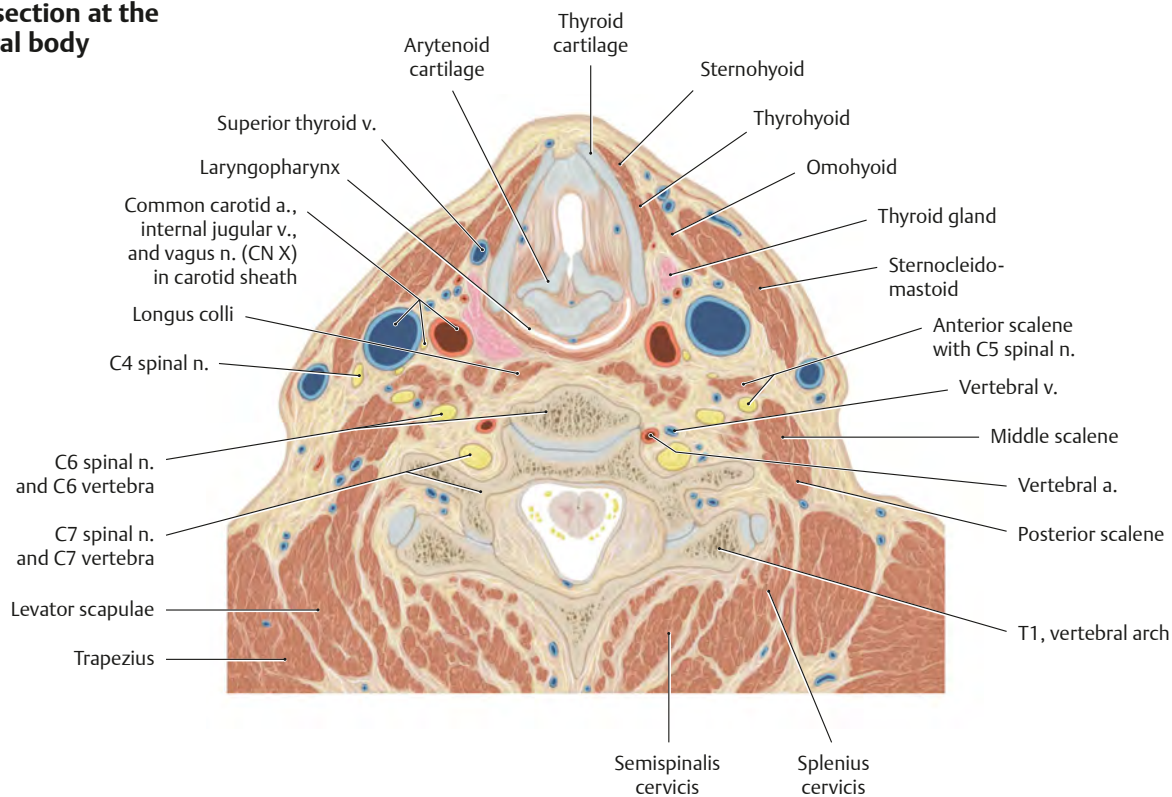
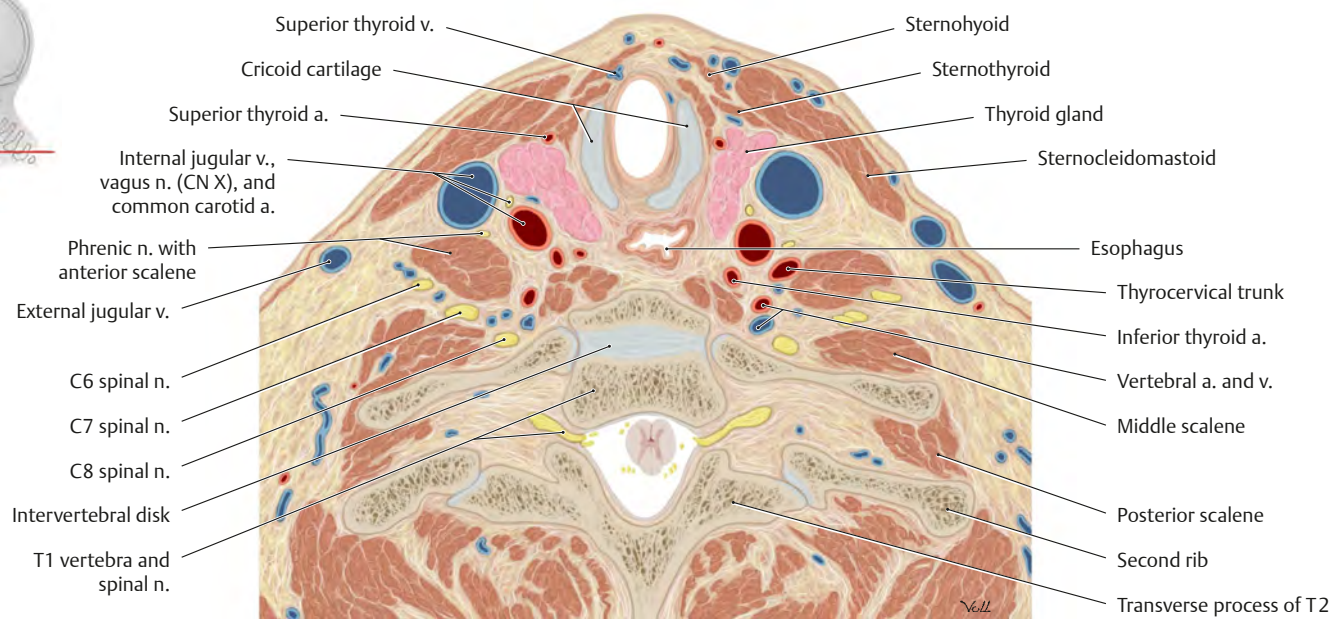


Fig. 46.11 Transverse section of the neck

Transverse section at the level of the C7/T1 vertebral junction. Inferior view. This section reveals the roots of spinal nerves C6 to C8 of the brachial plexus passing between the anterior and middle scalene muscles. The phrenic nerve is on the anterior surface of the anterior scalene and

the components of the carotid sheath (internal jugular vein, common carotid artery, and vagus nerve) lie in the interval between this muscle, the sternocleidomastoid, and the thyroid gland.



Radiographic Anatomy of the Head & Neck (I)

Fig. 46.12 Radiograph of the skull
Anteroposterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

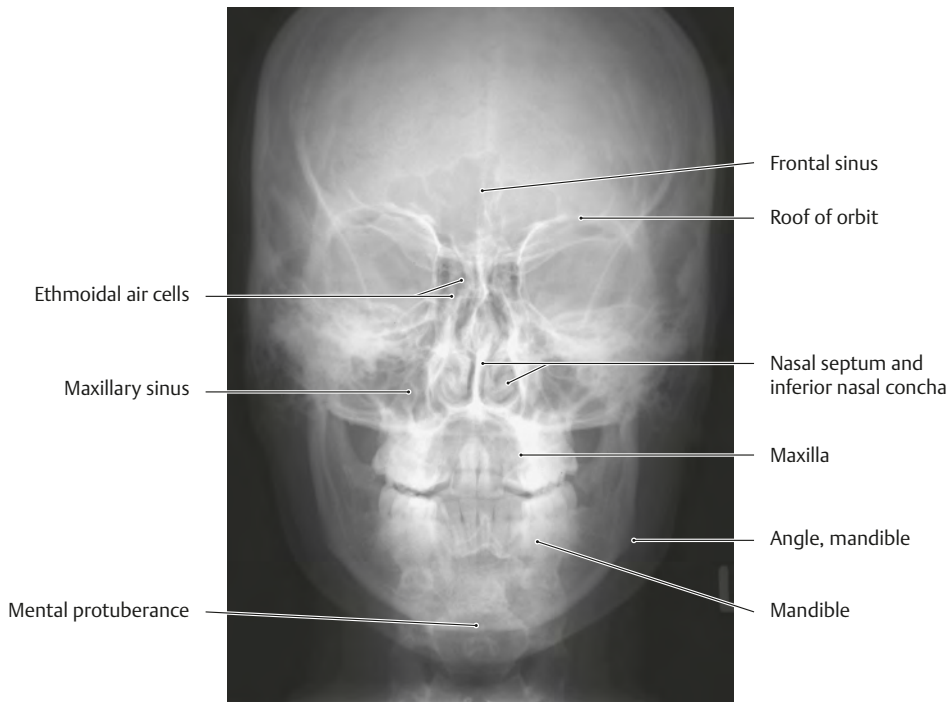


Fig. 46.13 Coronal MRI through the eyeball
Anterior view.

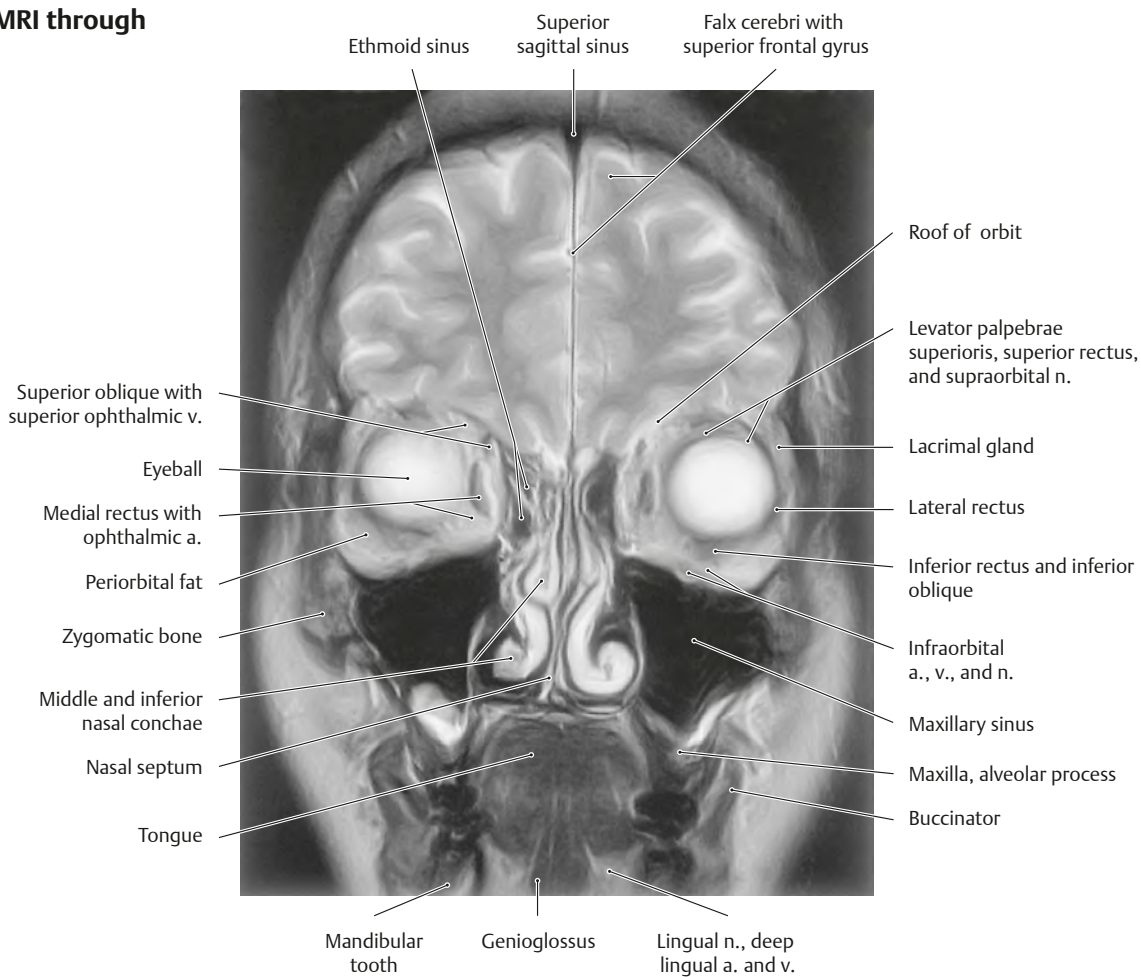
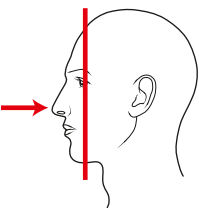
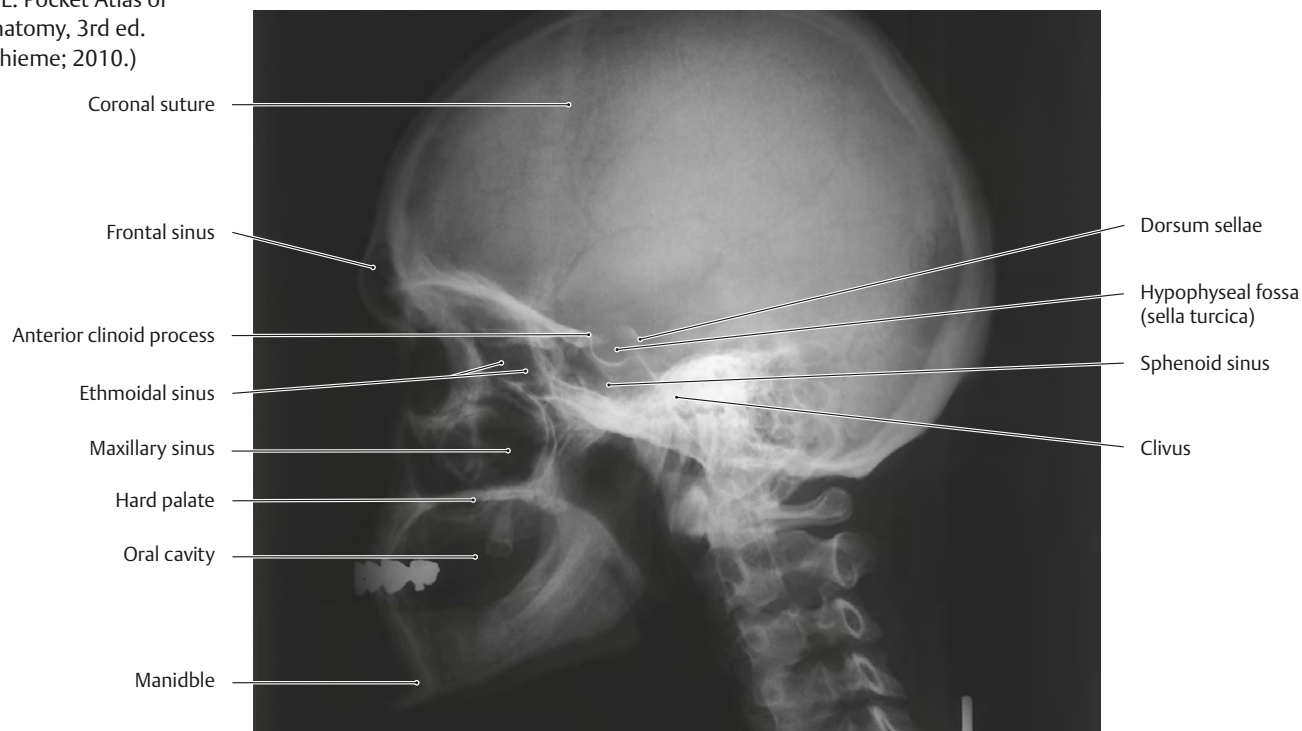


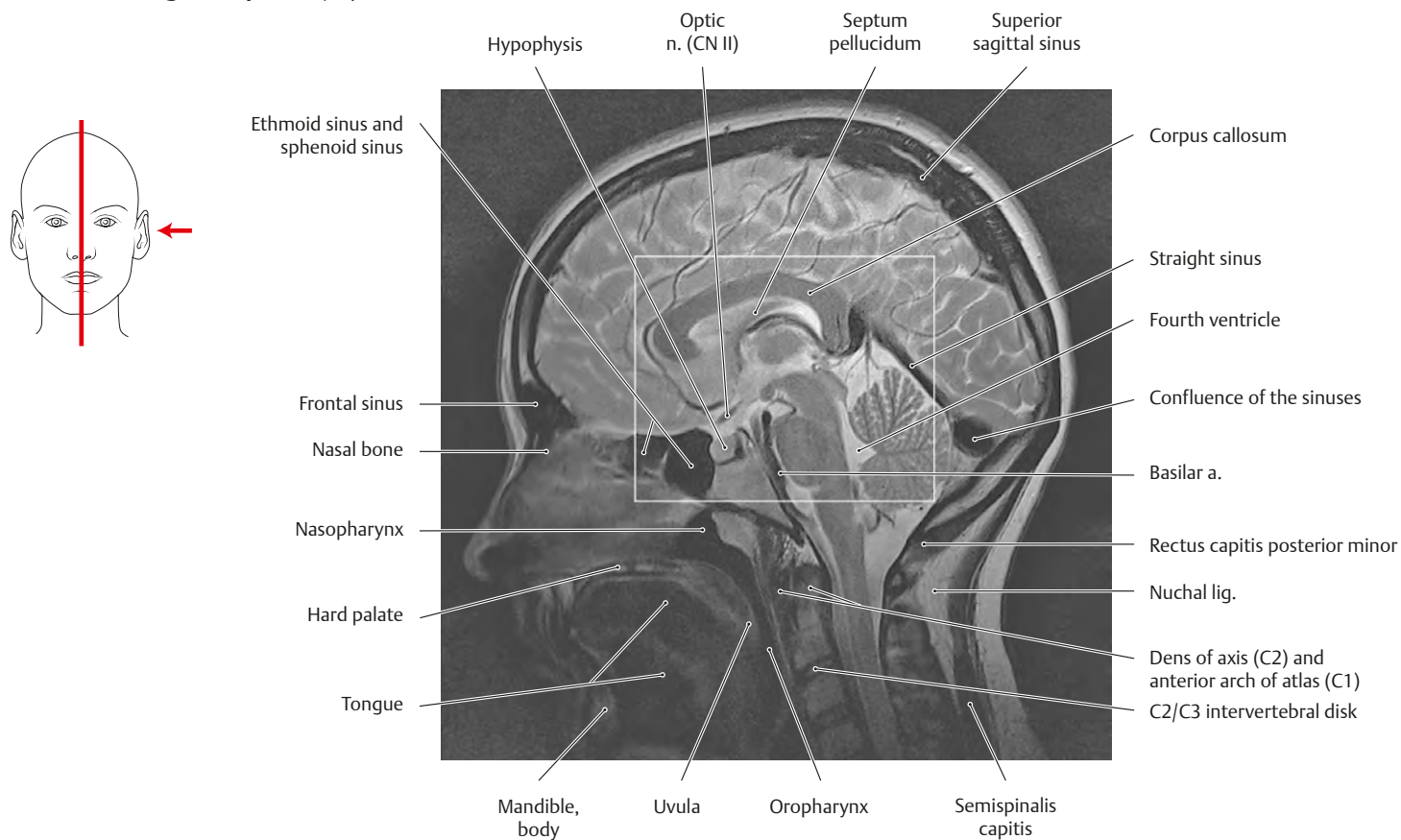
Fig. 46.14 Radiograph of the skull

Left lateral view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

**Fig. 46.15 Midsagittal MRI through the nasal septum**

Left lateral view. Boxed area represents the location of the ventricular system, thalamus, and pons. A more detail labeled version of this area can be seen in Fig. 51.5, p. 700. (Reproduced from Moeller TB, Reif E.

Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)



Radiographic Anatomy of the Head & Neck (II)

Fig. 46.16 Radiograph of the skull

Inferosuperior oblique view (Waters view). (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

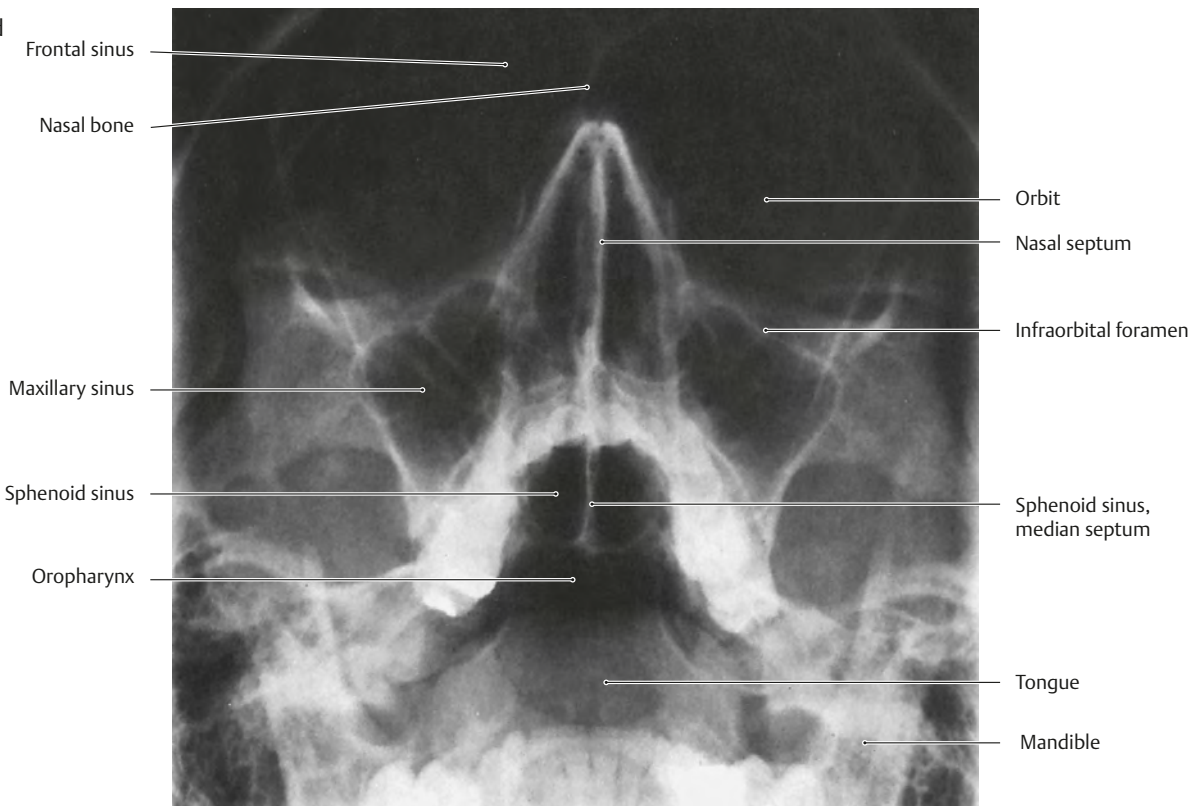


Fig. 46.17 Radiograph of the mandible

Left lateral view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Radiographic Anatomy, 3rd ed. New York, NY: Thieme; 2010.)

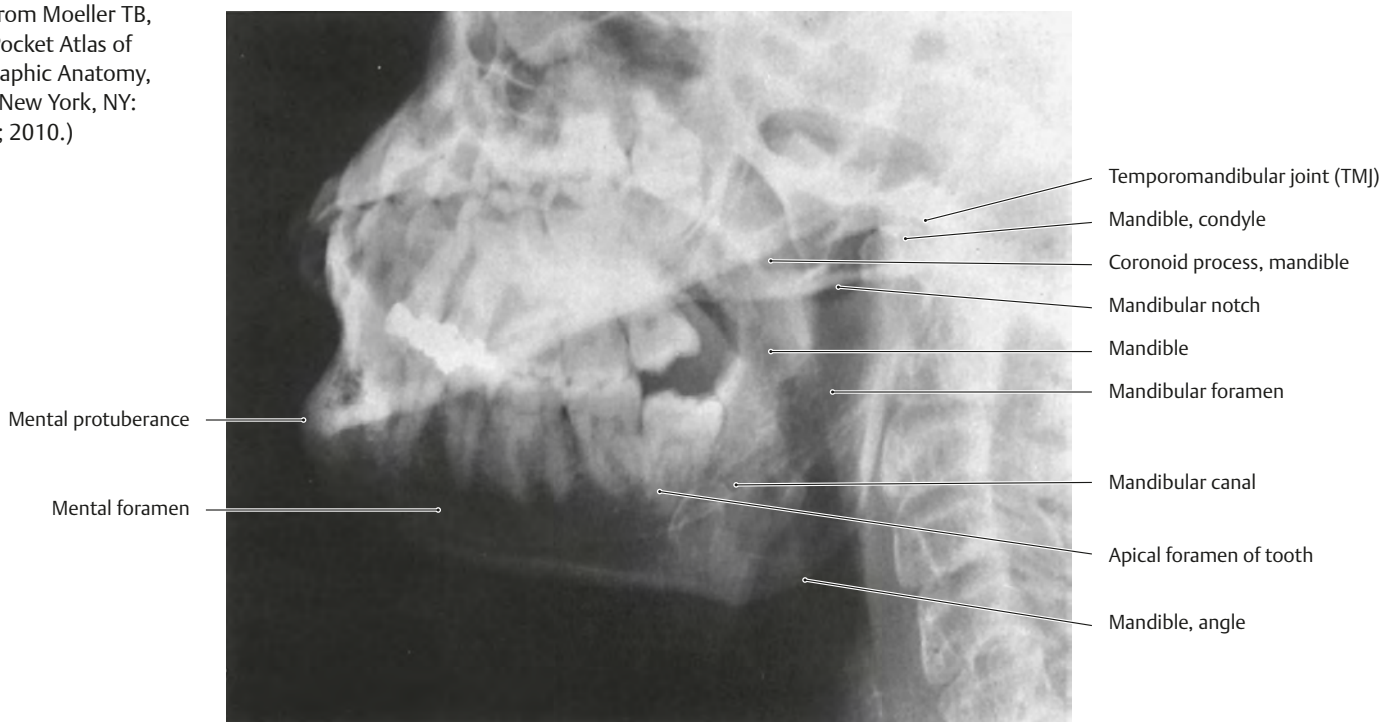


Fig. 46.18 Transverse MRI through the orbit and nasolacrimal duct

Inferior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)

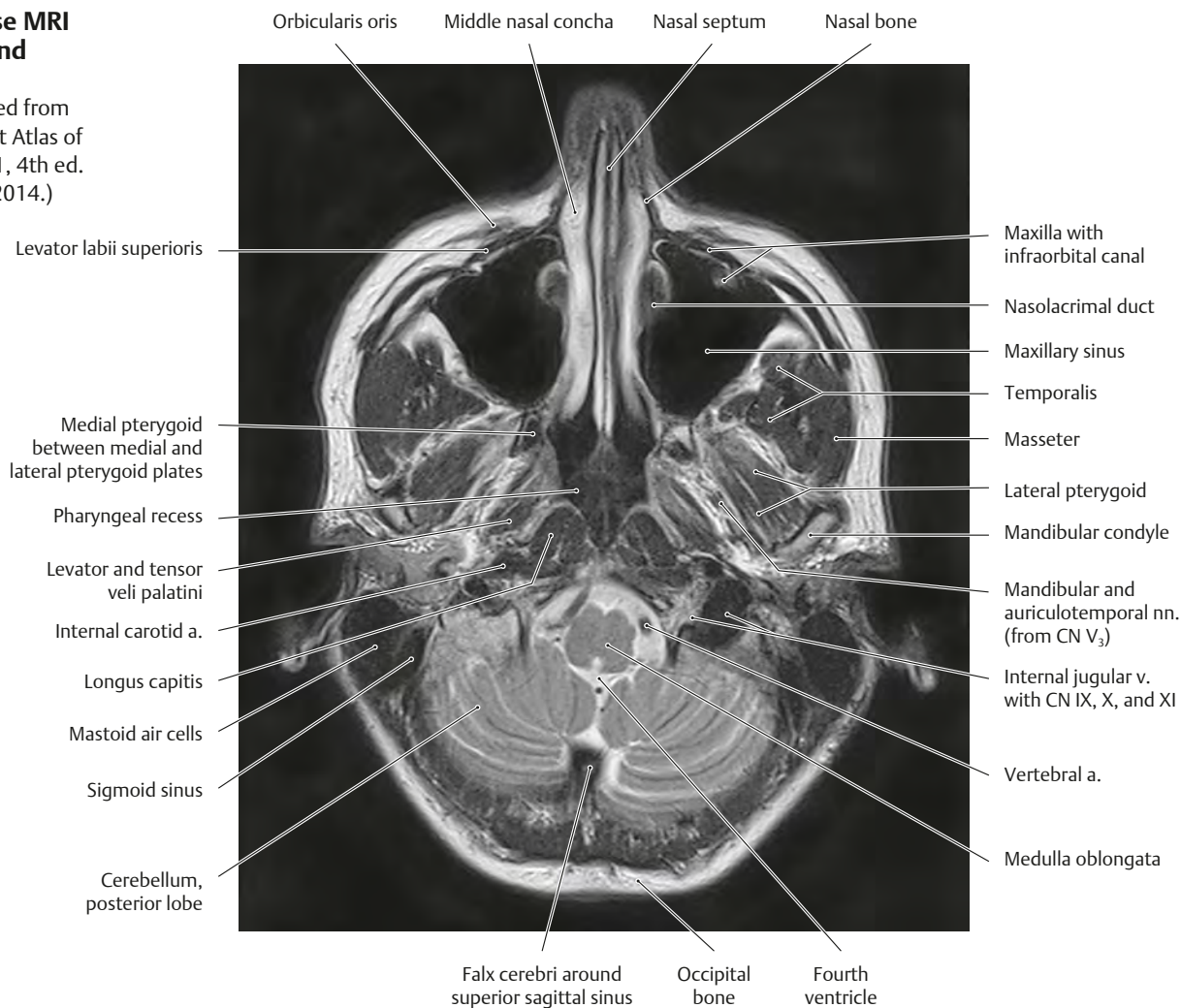
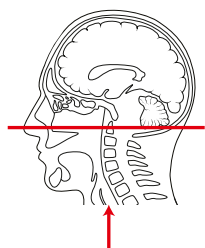
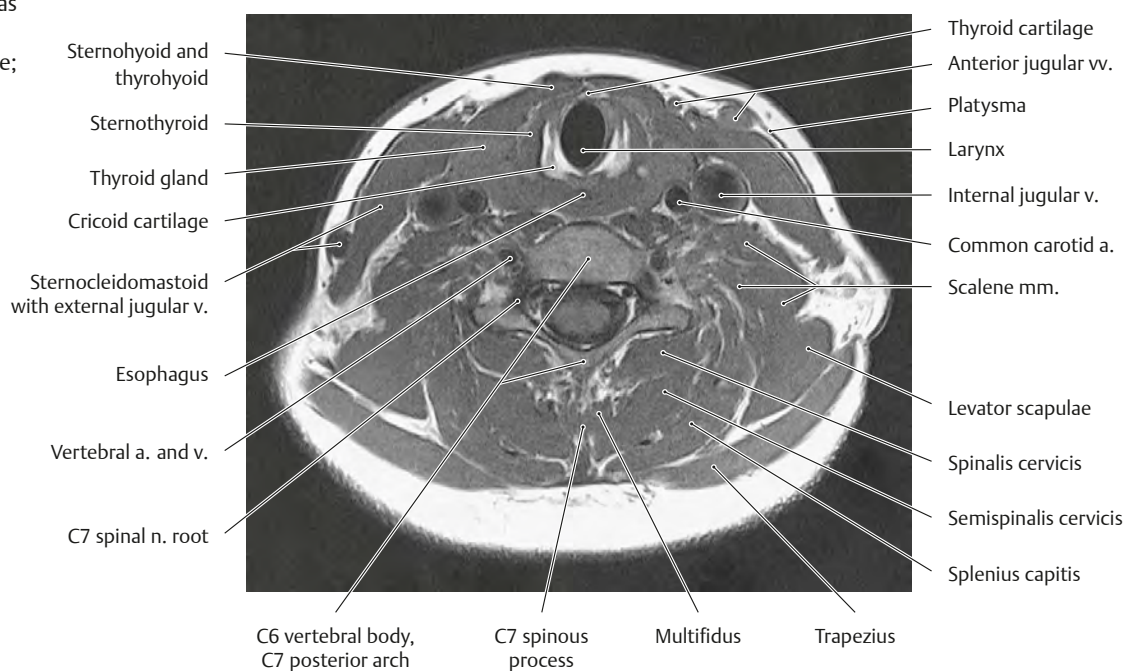
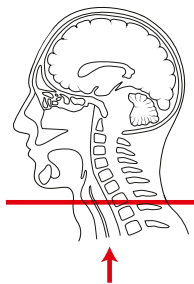


Fig. 46.19 Transverse MRI through the neck

Inferior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)



Radiographic Anatomy of the Head & Neck (III)

Fig. 46.20 CT scan of temporo-mandibular joint (TMJ)

Coronal section. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculo-skeletal System. New York, NY: Thieme; 2009.)

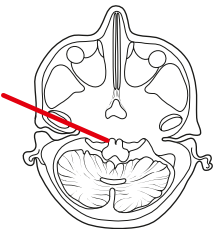


Fig. 46.21 CT scan of temporo-mandibular joint (TMJ)

Sagittal section, mouth closed. (Reproduced from Moeller TB, Reif E. Atlas of Sectional Anatomy: The Musculo-skeletal System. New York, NY: Thieme; 2009.)

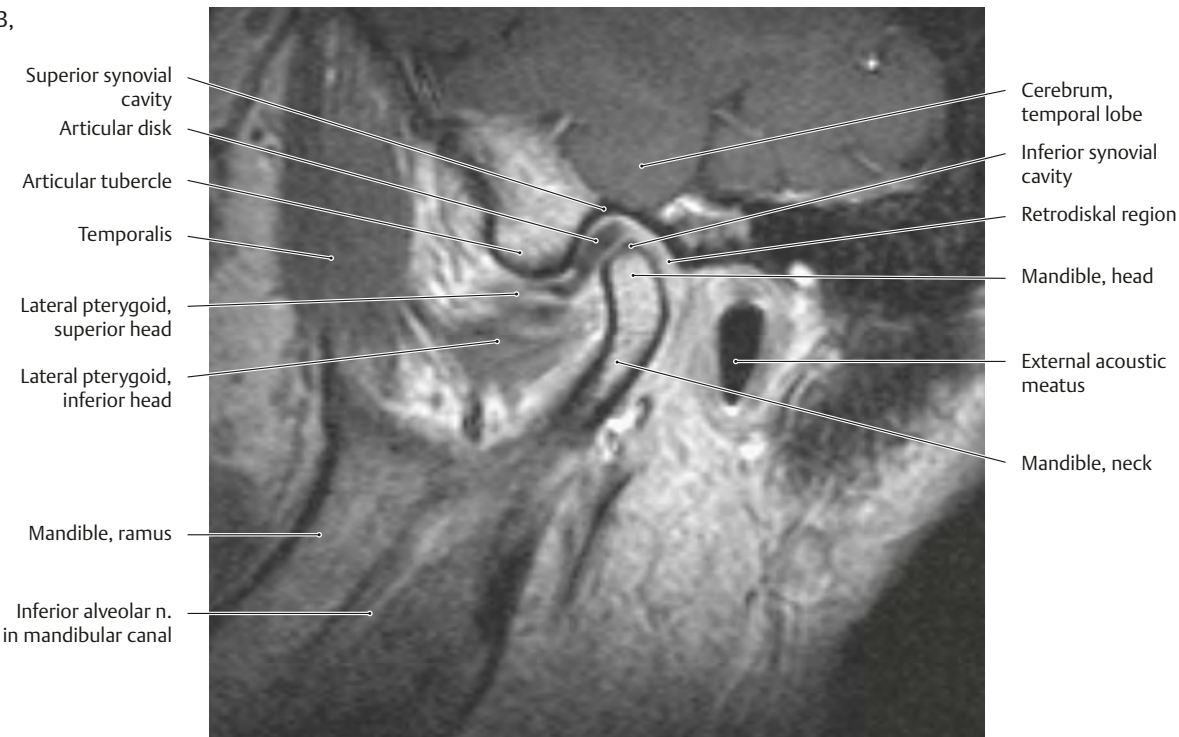
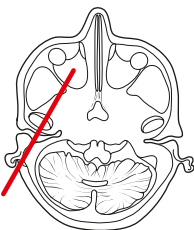
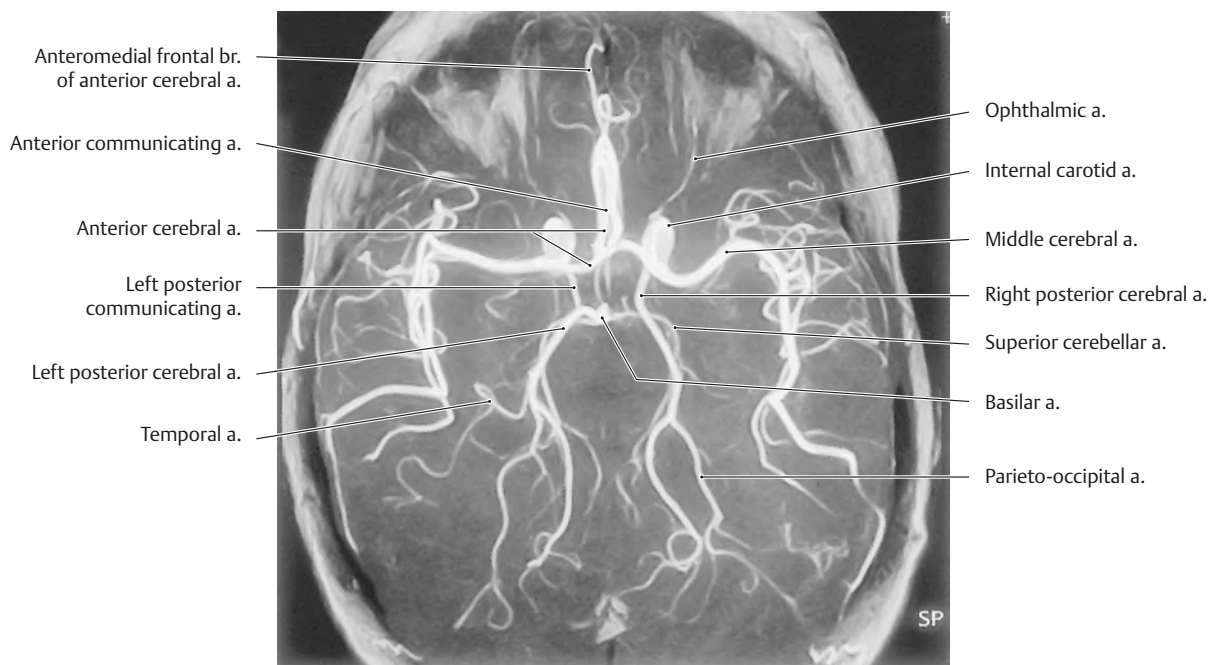
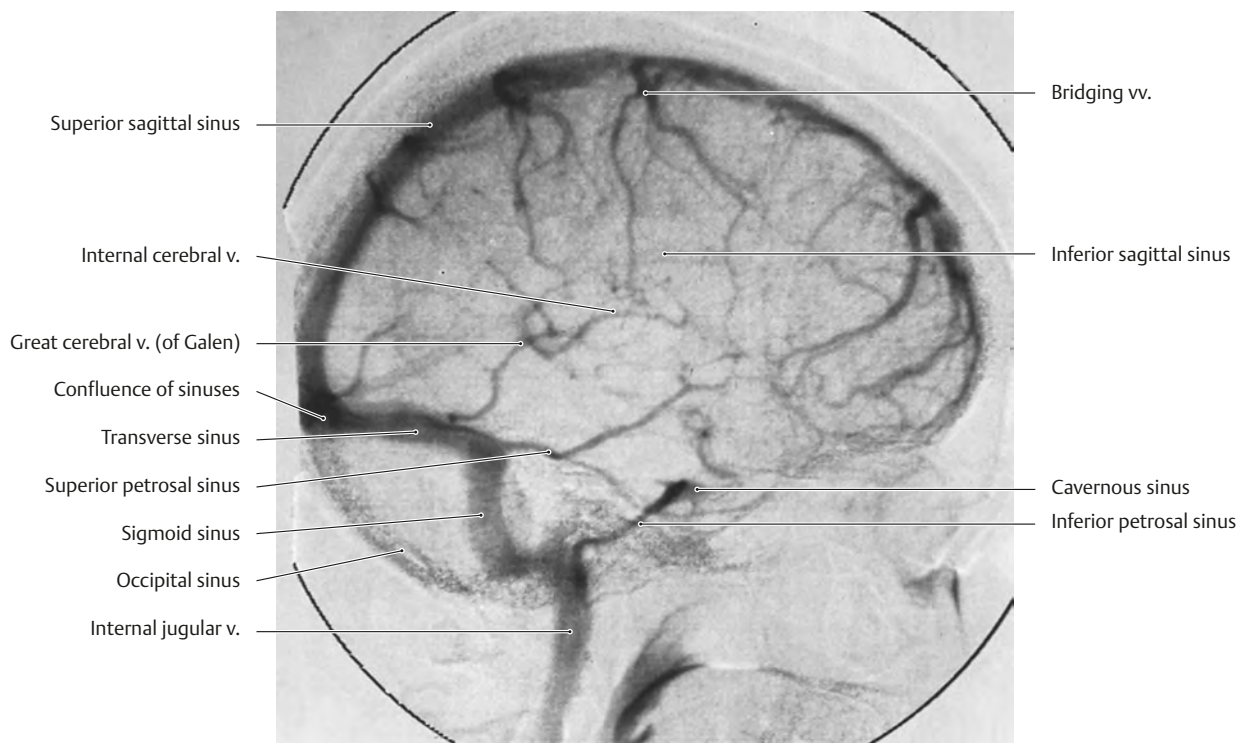


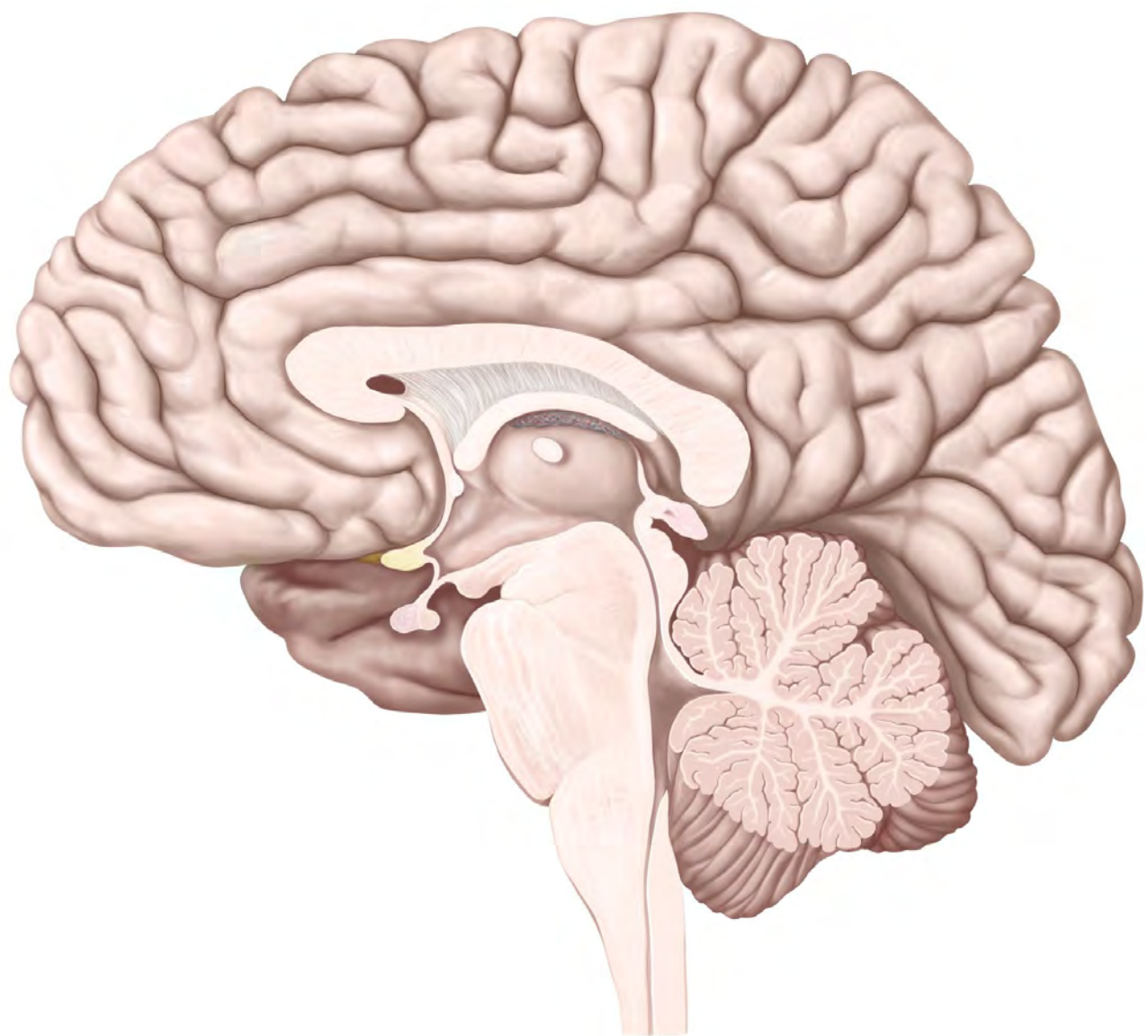
Fig. 46.22 Cranial MR angiography

Cranial view. In this angiogram note that the right posterior cerebral a. arises from the internal carotid artery instead of the basilar artery—a variant. The normal configuration is seen on the left side. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)

**Fig. 46.23 Dural venous sinus system of the head**

Right lateral view. Lateral internal carotid arteriogram, venous phase.





Brain & Nervous System

47 Brain

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47 Brain

Nervous System: Overview

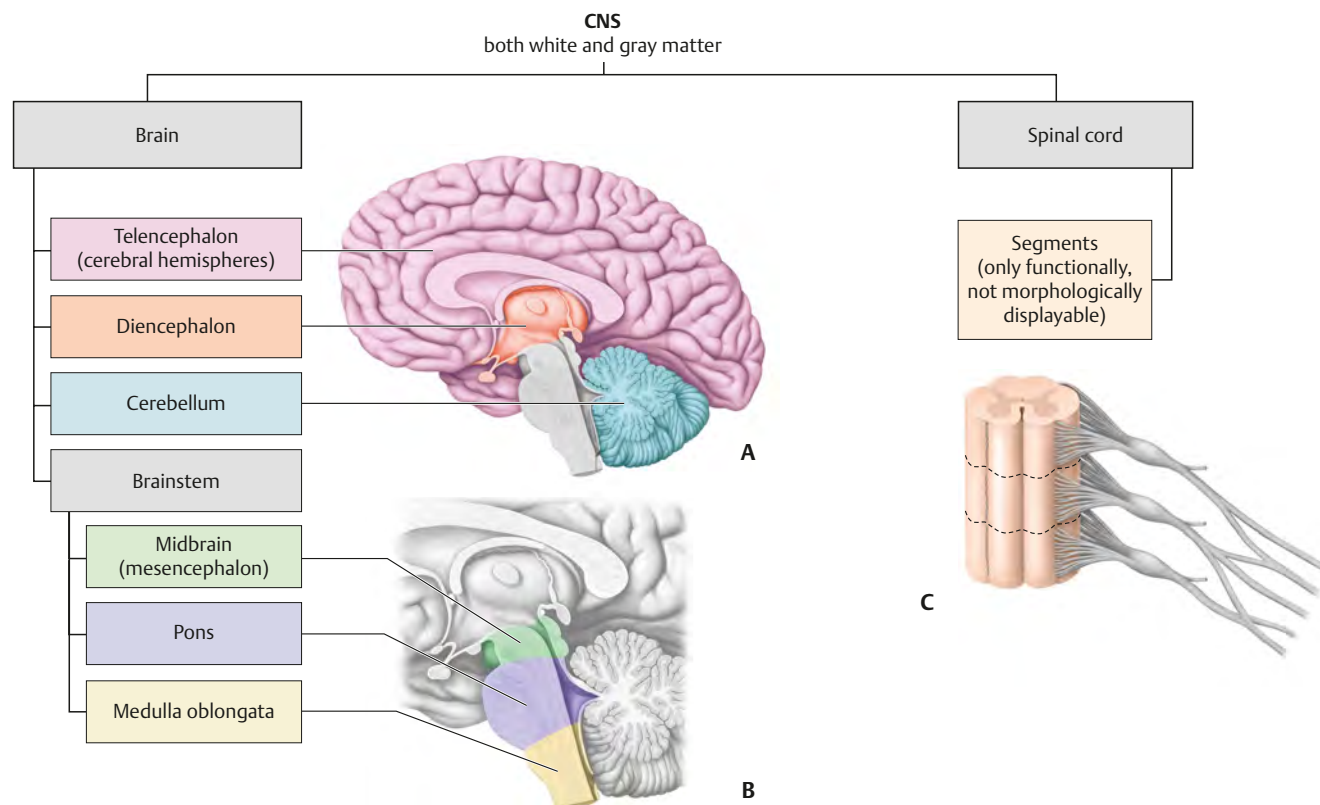


Fig. 47.1 Morphology of the Central Nervous System (CNS)

A and **B** Right side of the brain, medial view; **C** Section of the spinal cord, ventral view. A general morphological overview of the entire nervous system is necessary to help with understanding the material that follows. The CNS is divided into the brain and the spinal cord with the brain subdivided into the following regions:

- Cerebral hemispheres (telencephalon or endbrain)
- Interbrain (diencephalon)
- Cerebellum
- Brain stem composed of the midbrain (mesencephalon), pons (bridge) and medulla oblongata

In contrast, the other part of the CNS, the **spinal cord** appears morphologically rather as one homogenous structure. In terms of its functions, however, the spinal cord can also be divided into segments. The division of gray and white matter is clearly visible:

- Gray matter: centrally located, butterfly-shaped structure
- White matter: substance that surrounds the “butterfly”

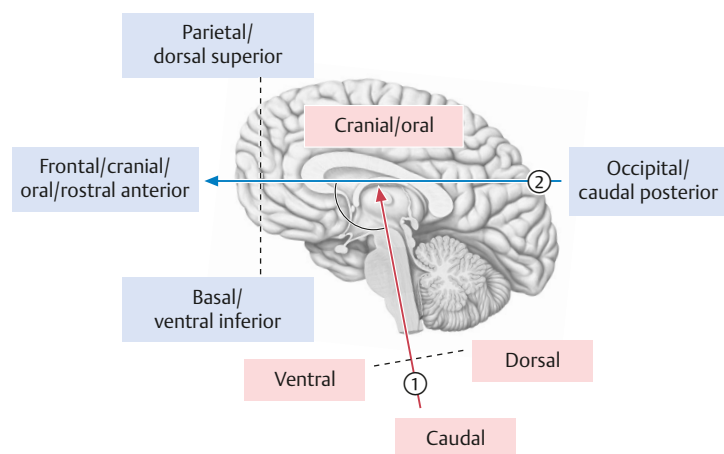


Fig. 47.2 Axes of the nervous system and directional terms

The same planes, axes and directional terms apply for both the entire body and the PNS. However, with the CNS, one differentiates between two axes:

- Axis No. 1: Meynert axis: It corresponds to the axes of the body and is used to designate locations in the spinal cord, brainstem (truncus encephali) and cerebellum.
- Axis No. 2: Forel axis. It turns horizontally through the diencephalon and telencephalon and forms an 80° angle to axis 1. As a result, the diencephalon and telencephalon lie “face down”.

Note: In order to avoid topographical misunderstandings, the following directional terms for axis No. 2 (Forel axis) are used:

- basal instead of ventral
- parietal instead of dorsal
- frontal and oral/rostral respectively instead of cranial
- occipital instead of caudal

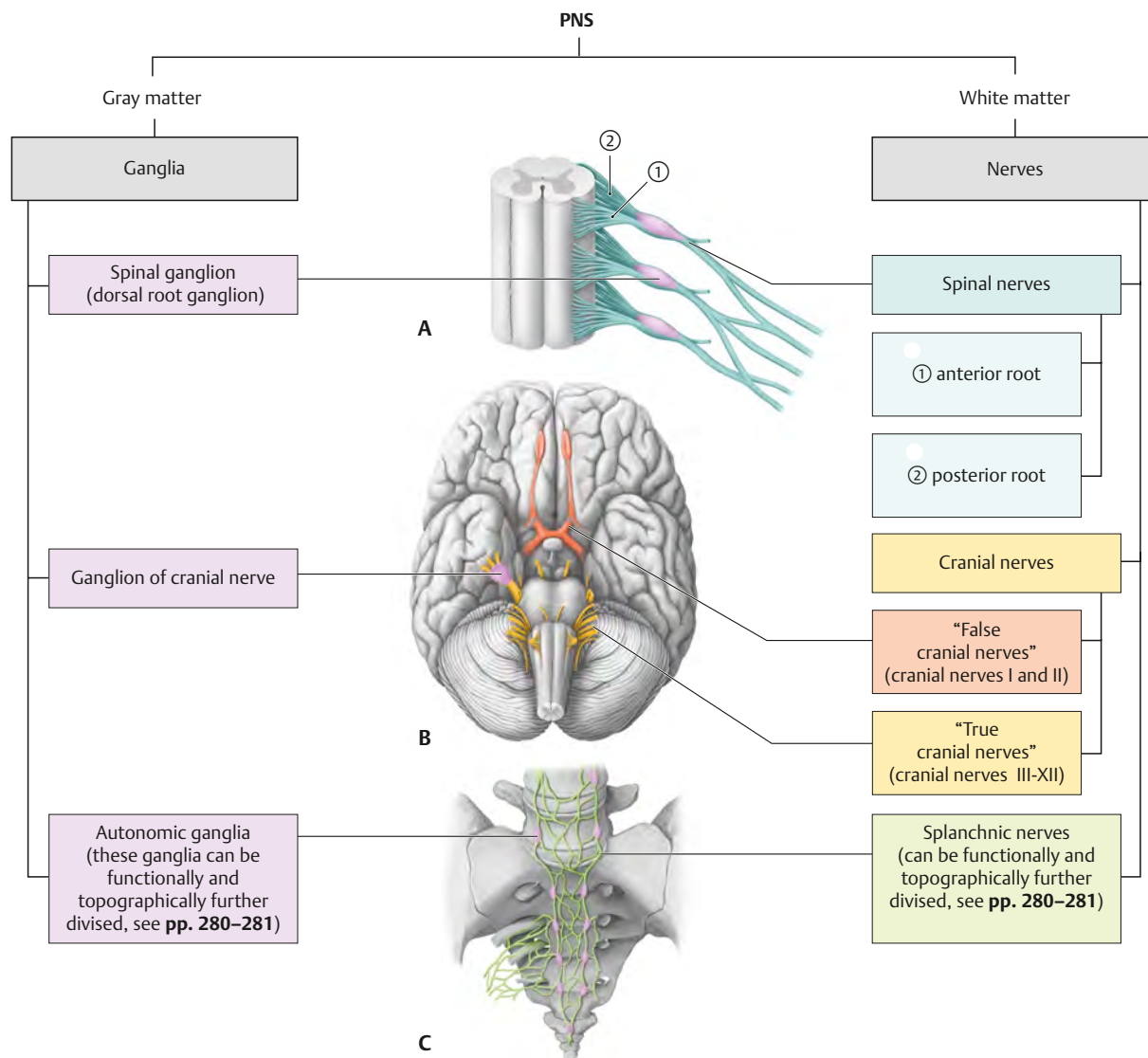


Fig. 47.3 Morphology of the peripheral nervous system

A Segment of the spinal cord, ventral view; **B** Base of the brain; **C** view of sympathetic ganglia and nerves located anterior to the sacrum.

The nerves and ganglia forming the peripheral nervous system are generally named for the part of the CNS with which they communicate:

- Spinal nerves (connect the periphery of the body with the spinal cord. Usually 31 or 32 pairs. Spinal nerves (except those related to vertebral levels T1 to T11 or T12) generally have their anterior rami form plexuses for reasons of functionality.
- Cranial nerves (connect the periphery of the body to the brain). 12 pairs.

Nerve cells found within ganglia (in the PNS) can be classified based on their affiliation with a particular functional division of the nervous system:

- Sensory neurons can be found within either division of the nervous system. In the PNS, sensory neurons are found within the sensory (dorsal root) ganglia on the posterior (dorsal) root of the spinal nerve.

In the CNS, sensory neurons are found within the sensory nuclei associated with the appropriate cranial nerves that contain sensory fibers.

- Ganglia of the autonomic nervous system contain postganglionic sympathetic and parasympathetic neurons that control the organs of the body. Autonomic ganglia are associated with splanchnic nerves that take vasomotor fibers to the viscera. The autonomic nervous system also demonstrates characteristic plexus formation.

Note: The distinction of sensory nerves in the CNS applies except for a few special cases. For instance, cranial nerves I (olfactory) and II (optic) are not true nerves but parts of the telencephalon or diencephalon, which clearly makes them part of the CNS. For historical reasons, they have been called “nerves”, which is systematically false. These “bogus” cranial nerves (colored red on the brain in the figure above) are often contrasted with the 10 true cranial nerves (colored yellow on this figure), which are clearly part of the PNS. In the interest of clarity, further details are located within each region throughout the atlas.

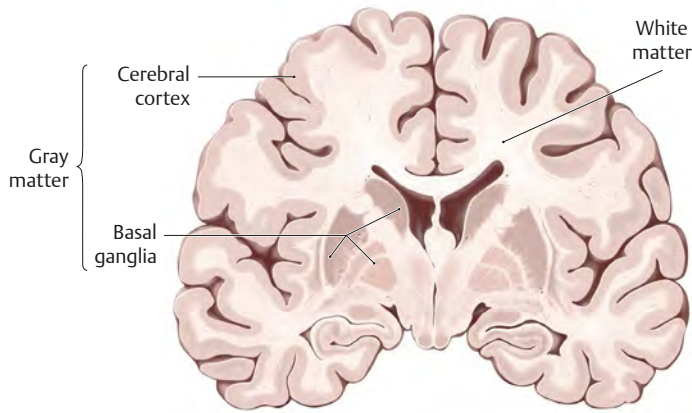
Nervous System: Development

Fig. 47.4 Central and peripheral nervous systems

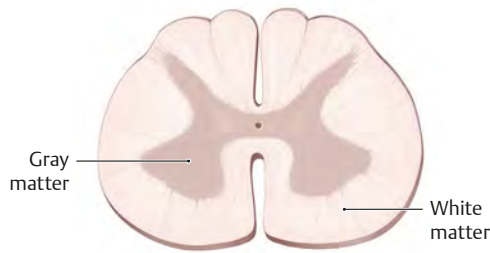
The CNS consists of the brain and spinal cord, which constitute a functional unit. The PNS consists of the nerves emerging from the brain and spinal cord (cranial and spinal nerves, respectively). Nerves emerging from the spinal canal after the end of the spinal cord, form the cauda equina (see p. 41)

Fig. 47.5 Gray and white matter in the CNS

Nerve cell bodies appear gray in gross inspection, whereas nerve cell processes (axons) and their insulating myelin sheaths appear white.



A Coronal section through the brain.



B Transverse section through the spinal cord.

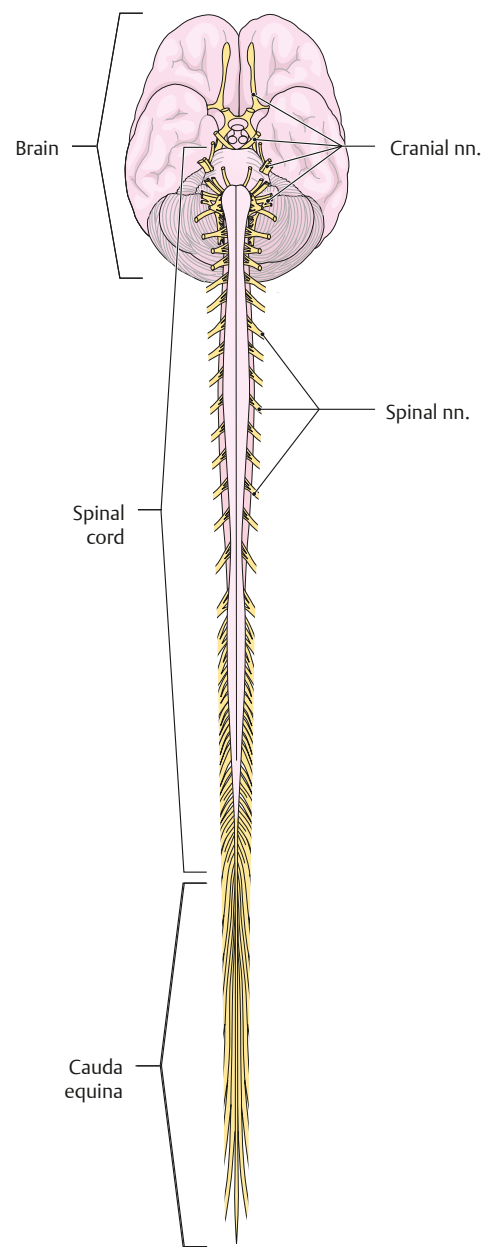
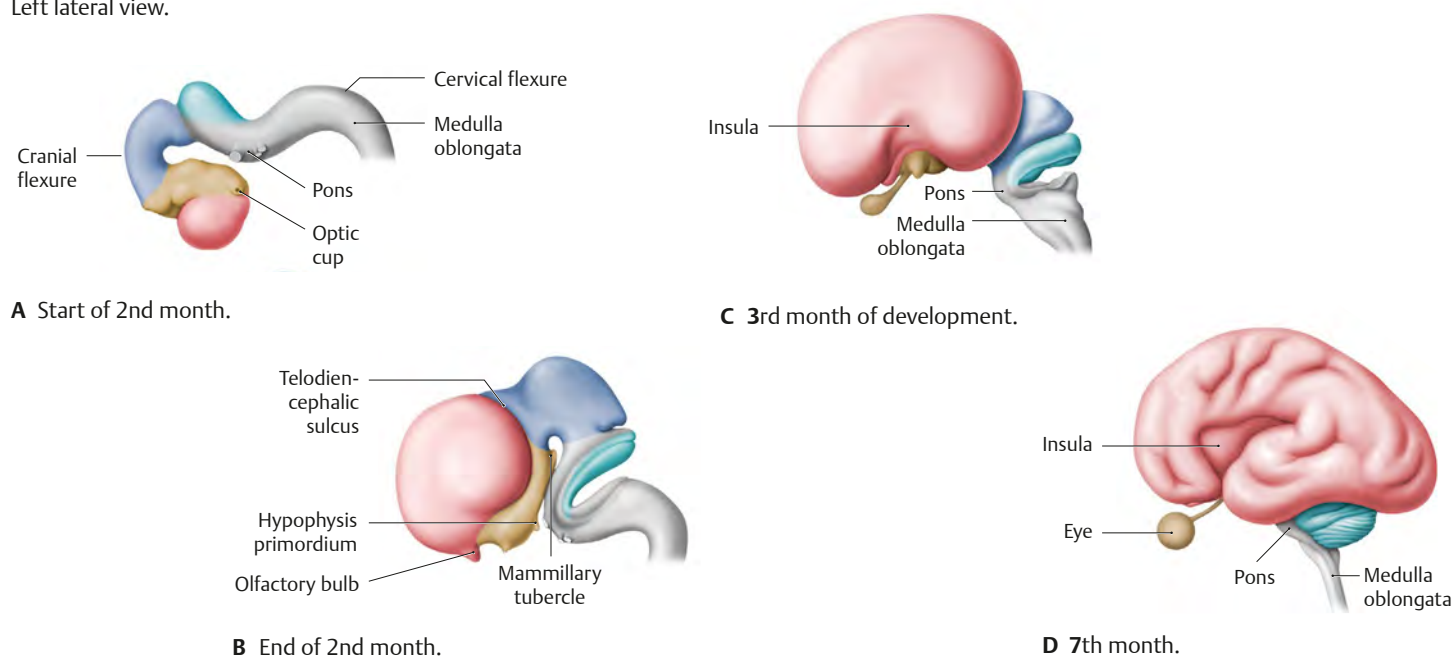


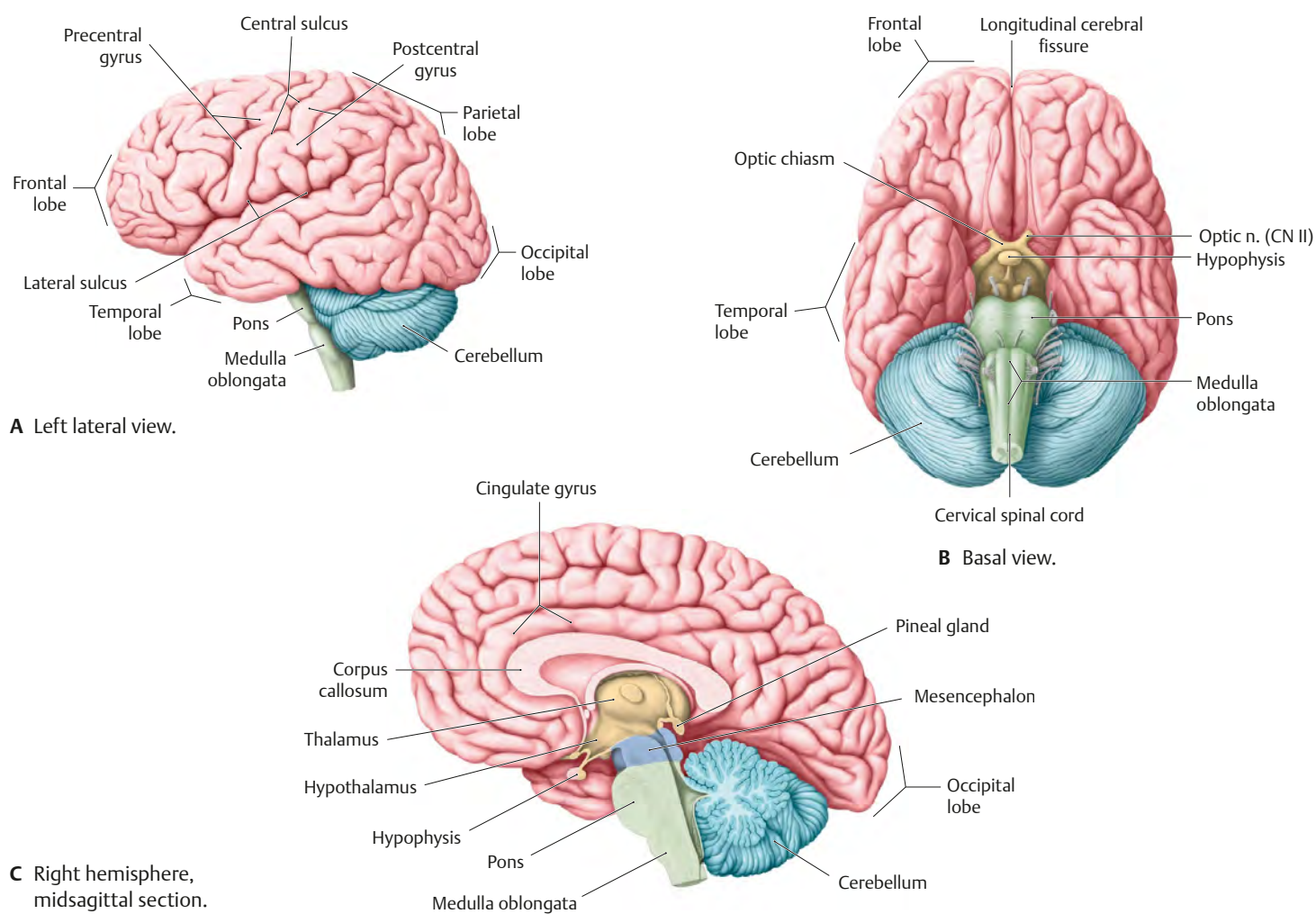
Table 47.1		Development of the brain		
Primary vesicle		Region		Structure
Neural tube	Prosencephalon (forebrain)	Telencephalon (cerebrum)		Cerebral cortex, white matter, and basal ganglia
		Diencephalon		Epithalamus (pineal), dorsal thalamus, subthalamus, and hypothalamus
	Mesencephalon (midbrain)*		Tectum, tegmentum, and cerebral peduncles	
	Rhombencephalon (hindbrain)	Metencephalon	Cerebellum	Cerebellar cortex, nuclei, and peduncles
			Pons*	Nuclei and fiber tracts
Myelencephalon	Medulla oblongata*			
* The mesencephalon, pons, and medulla oblongata are collectively known as the brainstem.				

Fig. 47.6 Embryonic development of the brain

Left lateral view.

**Fig. 47.7 Adult brain**

See Fig. 47.10 for lobes of the cerebrum. CN, cranial nerve.



Brain, Macroscopic Organization

Fig. 47.8 Cerebrum

Left lateral view. The cerebrum is part of the anterior subdivision of the embryonic forebrain (telencephalon)—the part of the adult forebrain that includes the cerebral hemispheres and associated structures. The

surface anatomy of the cerebrum can be divided macroscopically into 4 lobes: frontal, parietal, temporal, and occipital. The surface contours of the cerebrum are defined by convolutions (gyri) and depressions (sulci).

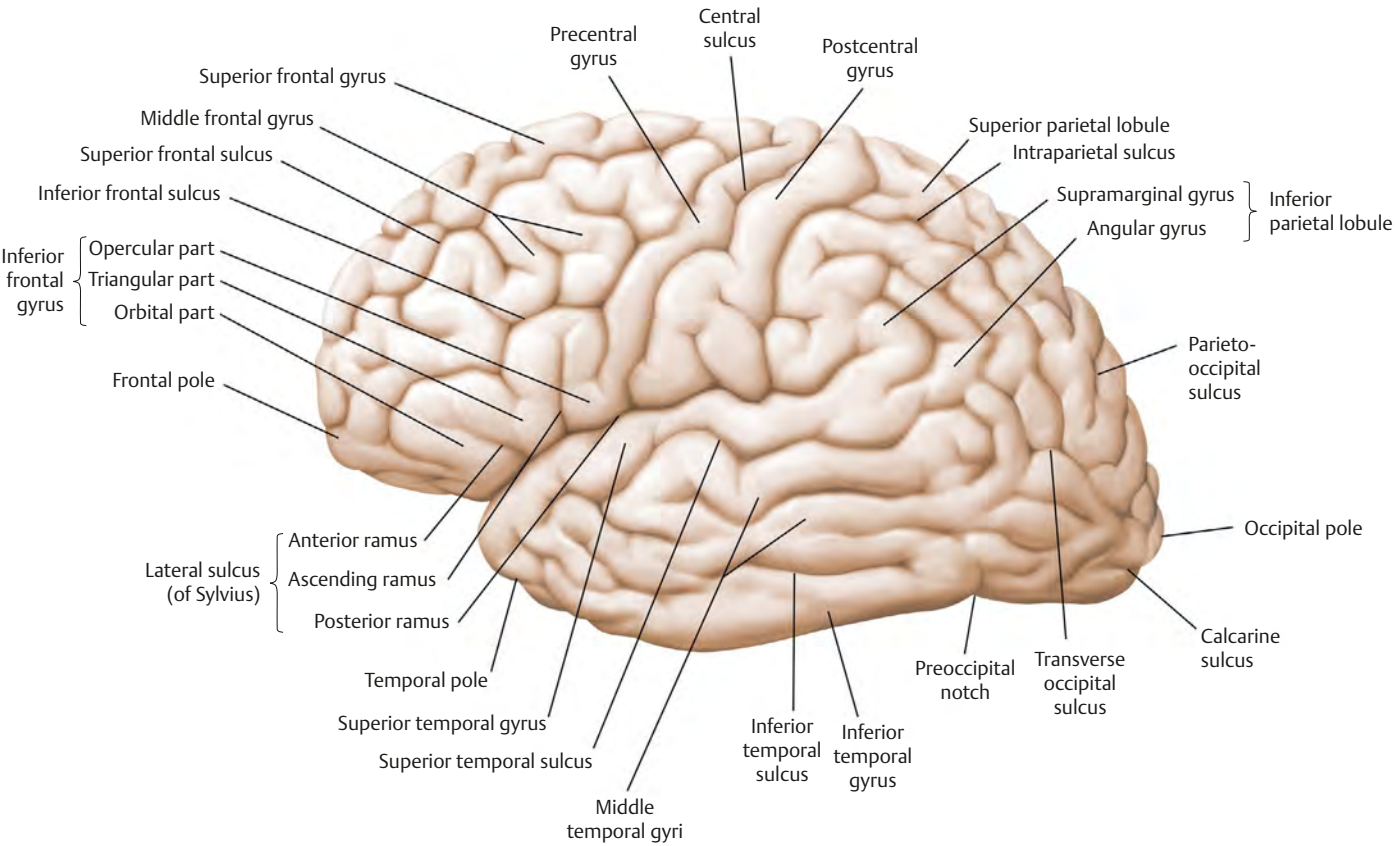


Fig. 47.9 Insular lobe

Lateral view of the retracted left cerebral hemisphere. Part of the cerebral cortex sinks below the surface during development forming the insula (or insular lobe). Those portions of the cerebral cortex that overlie this deeper cortical region are called opercula ("little lids").

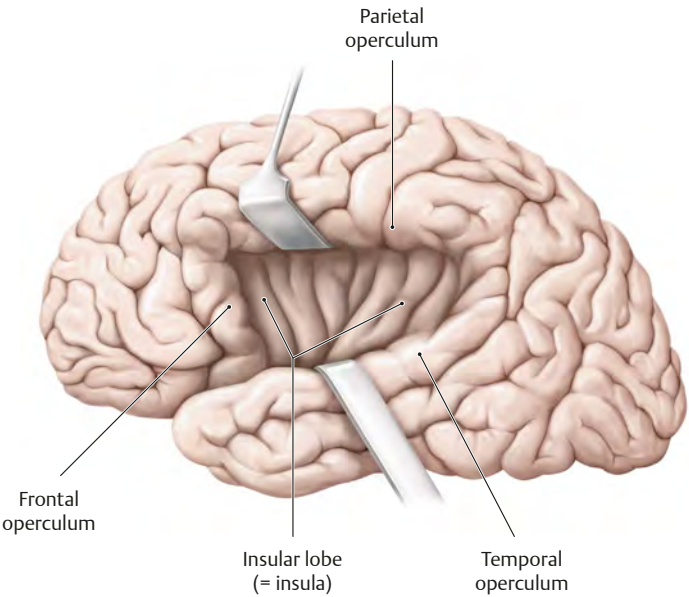
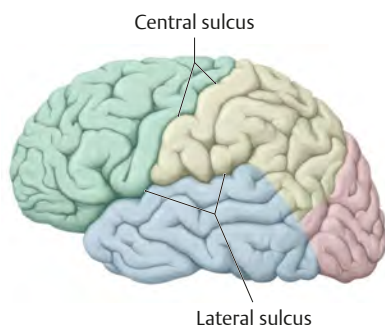
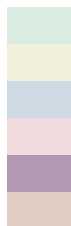


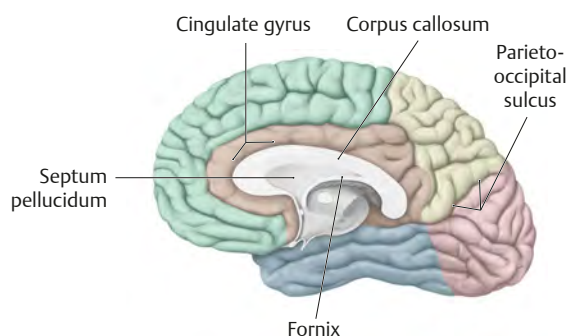
Fig. 47.10 Lobes in the cerebral hemispheres

The isocortex also may be functionally divided into association areas (lobes).

Frontal lobe
Parietal lobe
Temporal lobe
Occipital lobe
Insular lobe (insula)
Limbic lobe (limbus)

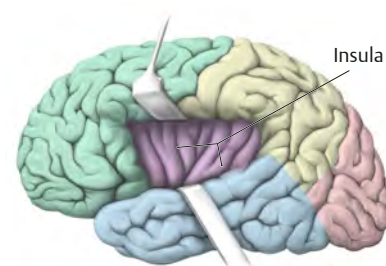


A Left hemisphere, lateral view.

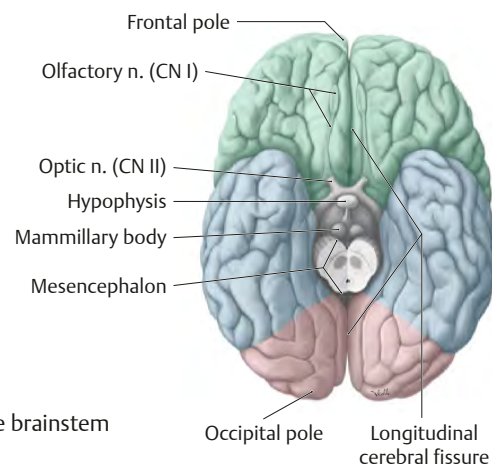


C Right hemisphere, medial view.

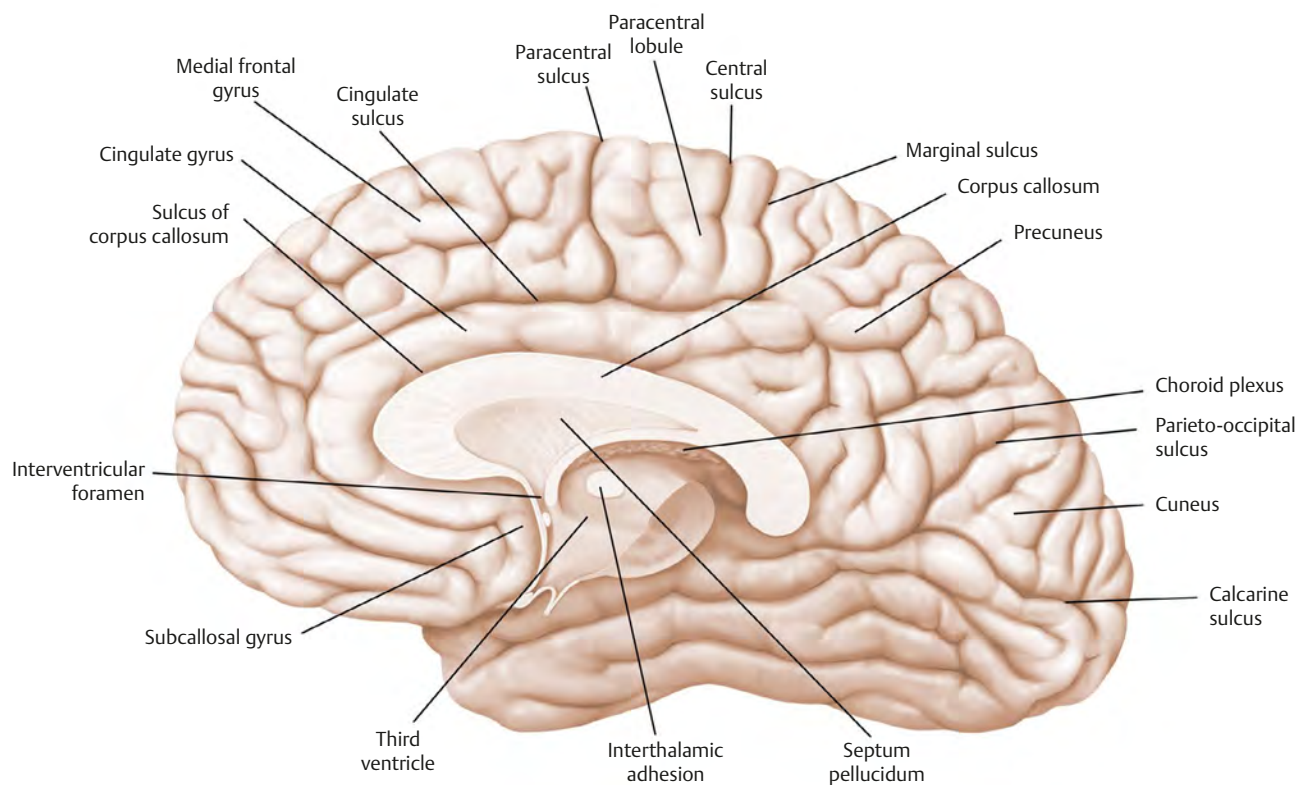
B Lateral view of the retracted left cerebral hemisphere.



D Basal view with the brainstem removed.

**Fig. 47.11 Midsagittal section of the brain showing the medial surface of the right hemisphere**

The brain has been split along the longitudinal cerebral fissure.



Diencephalon

The diencephalon is the posterior subdivision of the forebrain—the part of the adult forebrain that includes the thalamus and associated structures.

Fig. 47.12 Diencephalon

Right hemisphere, midsagittal section, medial view. The major components of the diencephalon are the thalamus, hypothalamus, and hypophysis (anterior lobe). The diencephalon is located below the corpus callosum, part of the cerebrum, and above the midbrain. The thalamus makes up four-fifths of the diencephalon but the only parts that can be seen externally are the hypothalamus (seen on the basal aspect of the brain) and portions of the epithalamus. In the adult brain the diencephalon is involved in endocrine functioning and autonomic coordination of the pineal, neurohypophysis, and hypothalamus. It also acts as a relay station for sensory information and somatic motor control via the thalamus.

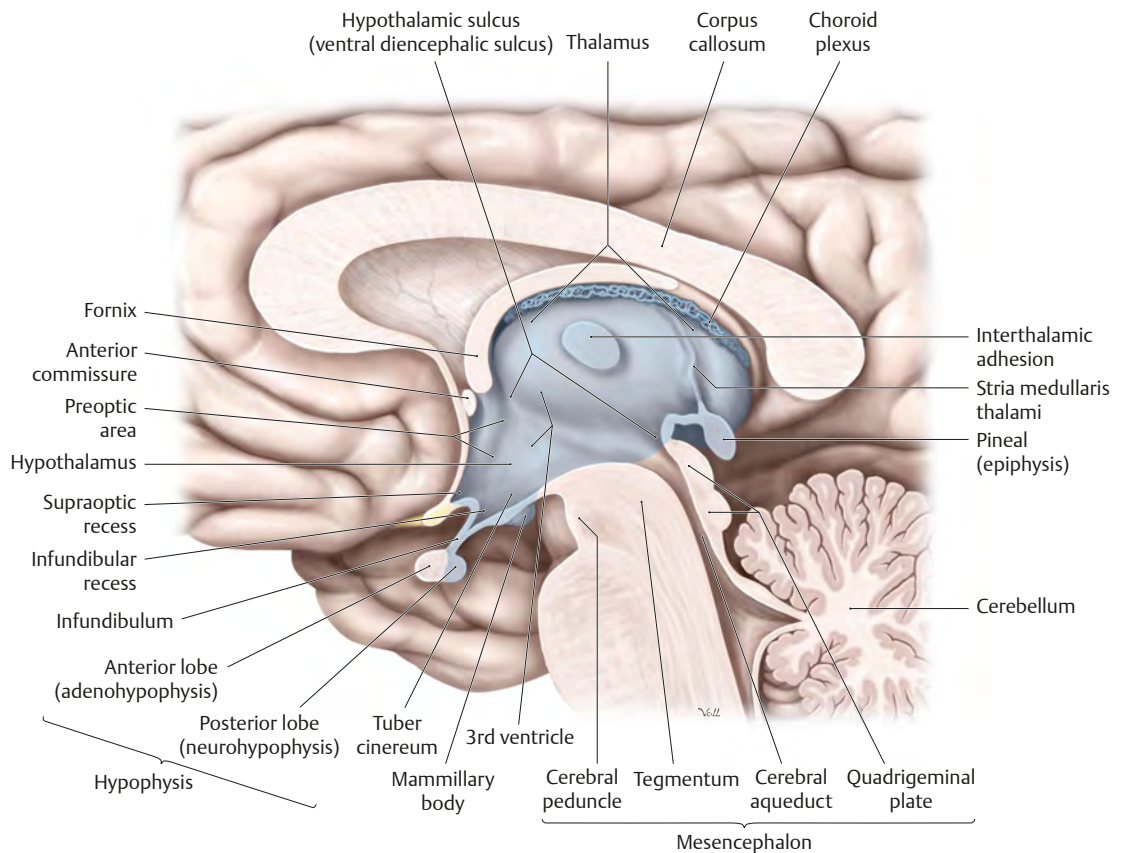


Fig. 47.13 Arrangement of the diencephalon around the third ventricle

Oblique transverse section through the telecephalon with the corpus callosum, fornix, and choroid plexus removed, posterior view. This figure clearly illustrates that the lateral wall of the third ventricle forms the medial boundary of the diencephalon.

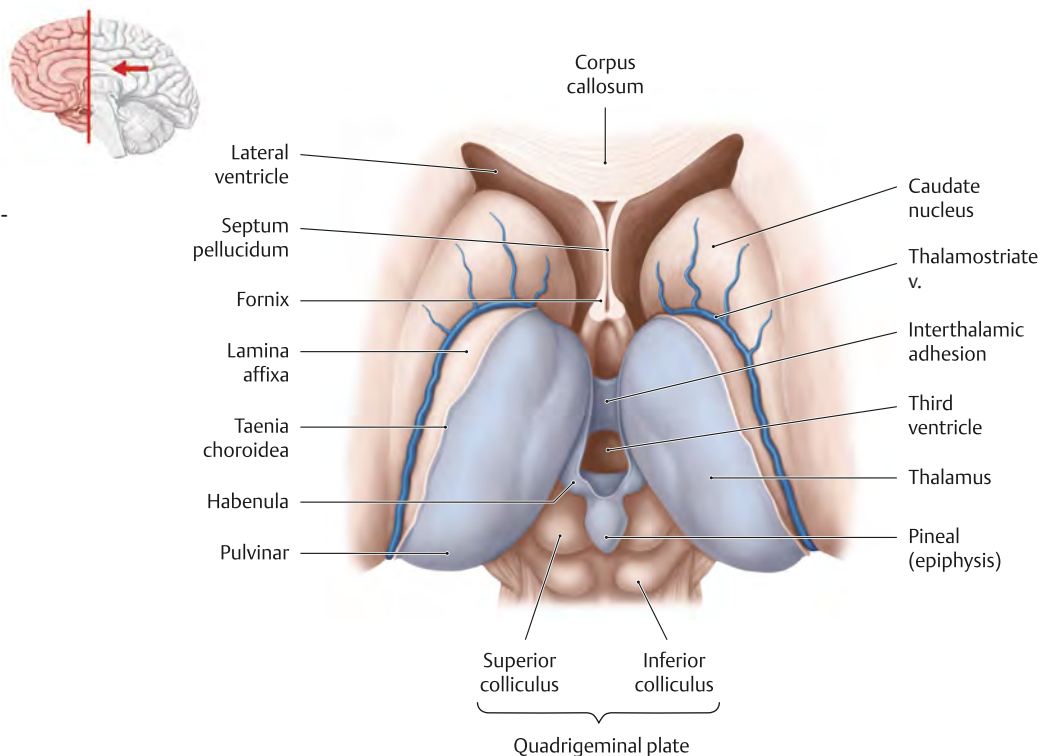


Fig. 47.14 The diencephalon and brainstem

Left lateral view. The cerebral hemispheres have been removed from around the thalamus. The cerebellum has also been removed. The parts of the diencephalon visible in this dissection are the thalamus, the lateral geniculate body, and the optic tract. The latter two are components of the visual pathway. This dissection illustrates the role the diencephalon plays in linking the underlying brainstem to the overlying cerebral hemispheres.

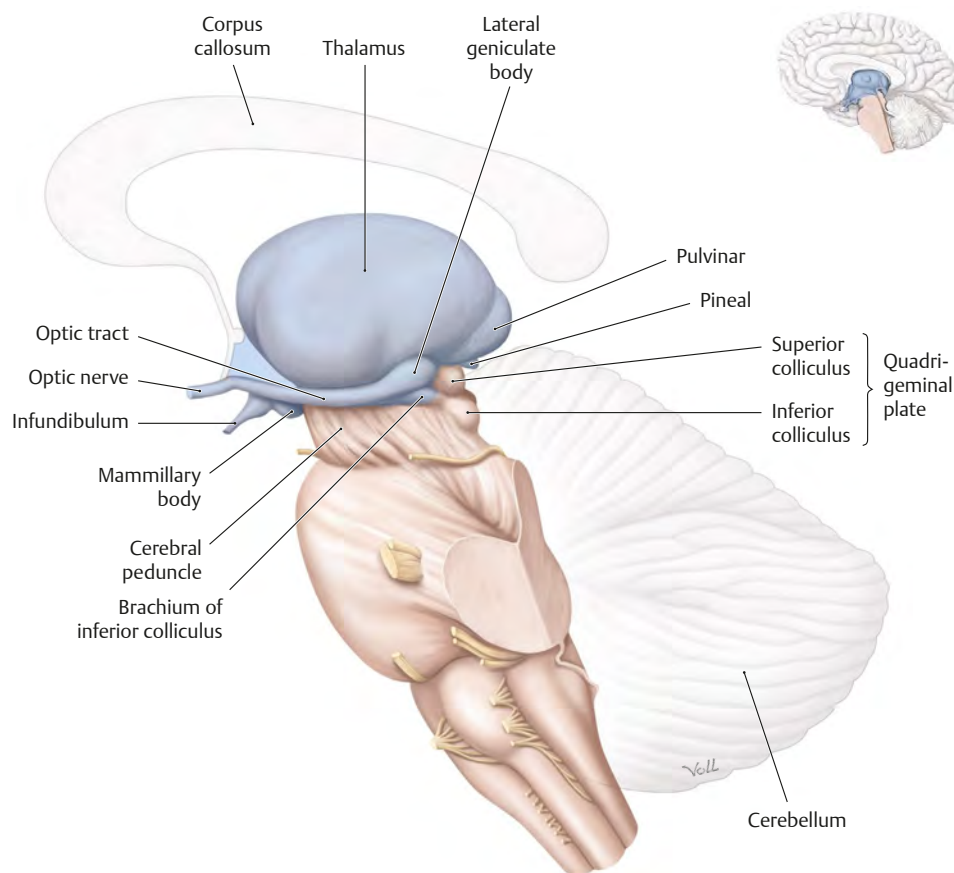
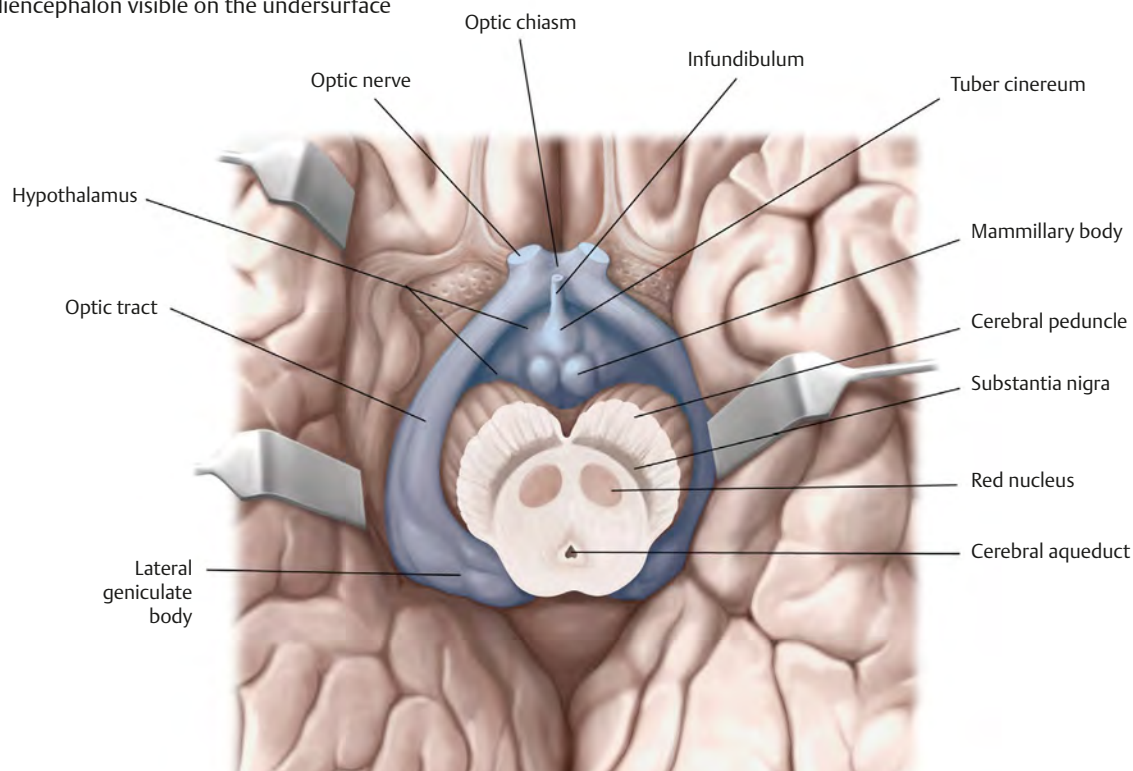


Fig. 47.15 Location of the diencephalon in the adult brain

Basal view of the brain (brainstem has been sectioned at the level of the pons). The structures that can be identified in this view represent those parts of the diencephalon situated on the basal surface of the brain. This view also demonstrates how the optic tract winds around the cerebral peduncles. The expansion of the telencephalon during development limits the number of structures of the diencephalon visible on the undersurface of the brain. They are:

- Optic nerve
- Optic chiasm
- Optic tract
- Tuber cinereum with the infundibulum
- Mammillary bodies
- Lateral geniculate body
- Neurohypophysis



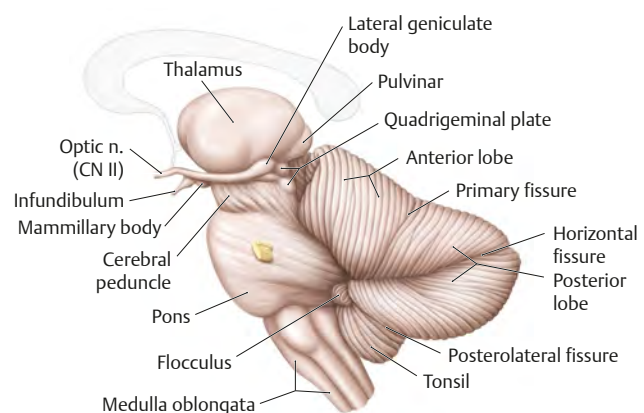
Brainstem & Cerebellum

The stalk-like region of the brain connecting the cerebral hemispheres to the cerebellum and spinal cord consists of the diencephalon (thalamus and associated structures) and the brainstem—composed of the mesencephalon or midbrain, pons and medulla oblongata moving

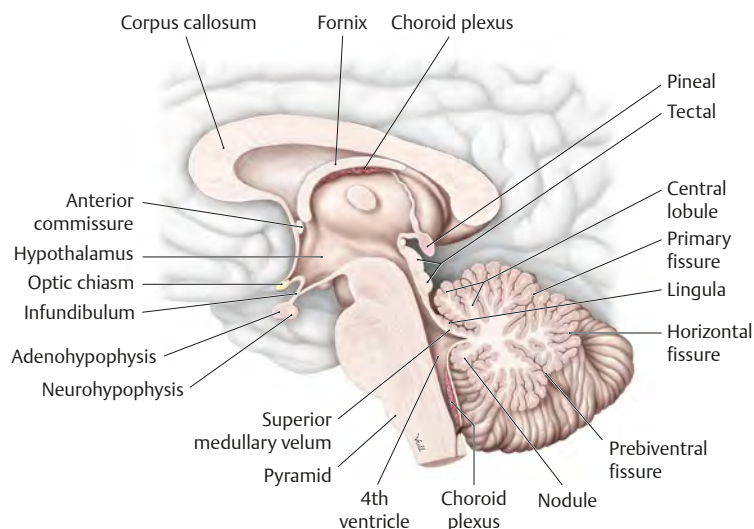
sequentially caudal. Fiber bundles pass through this region from the spinal cord on their way to and from the cerebrum; thick fiber bundles pass contralaterally from the cerebrum into the cerebellar hemispheres; and 10 of the 12 cranial nerves are associated with the brainstem.

Fig. 47.16 Diencephalon, brainstem, and cerebellum

Left lateral view.

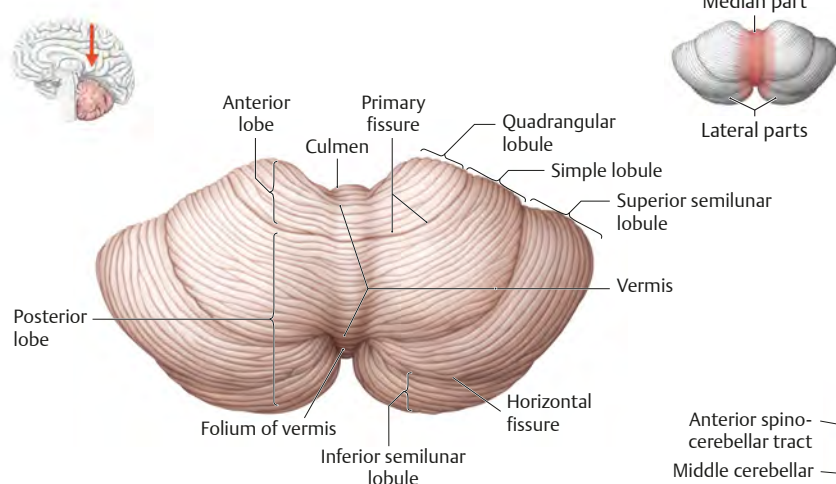


A Isolated structures.

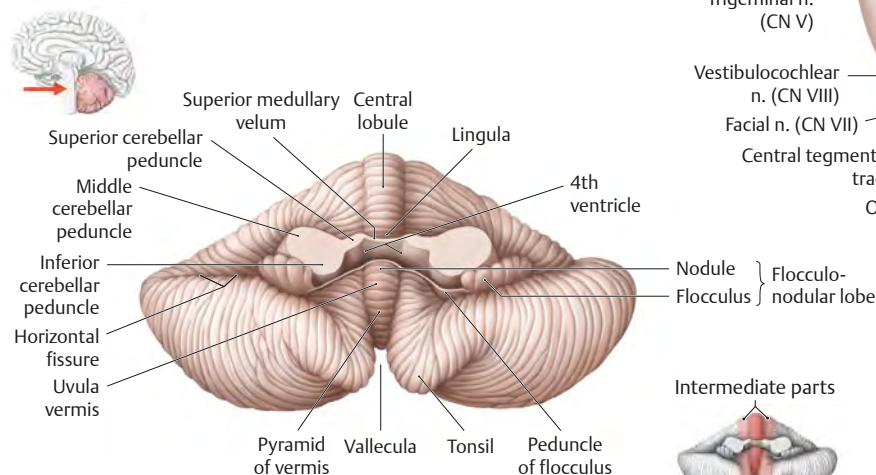


B Midsagittal section.

Fig. 47.17 Cerebellum



A Superior view.



B Anterior view.

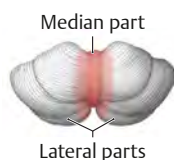
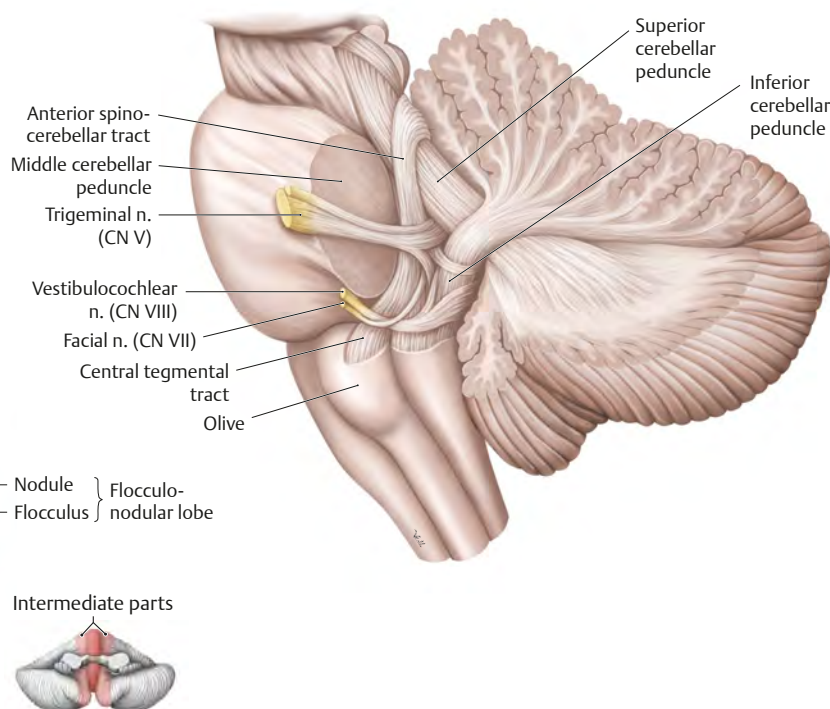


Fig. 47.18 Cerebellar peduncles

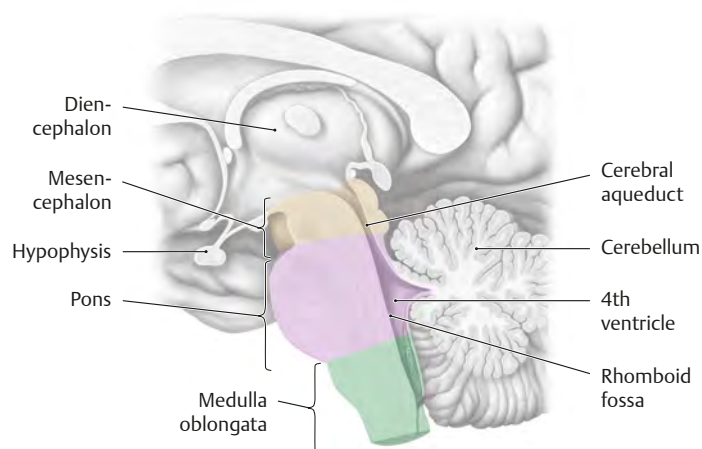
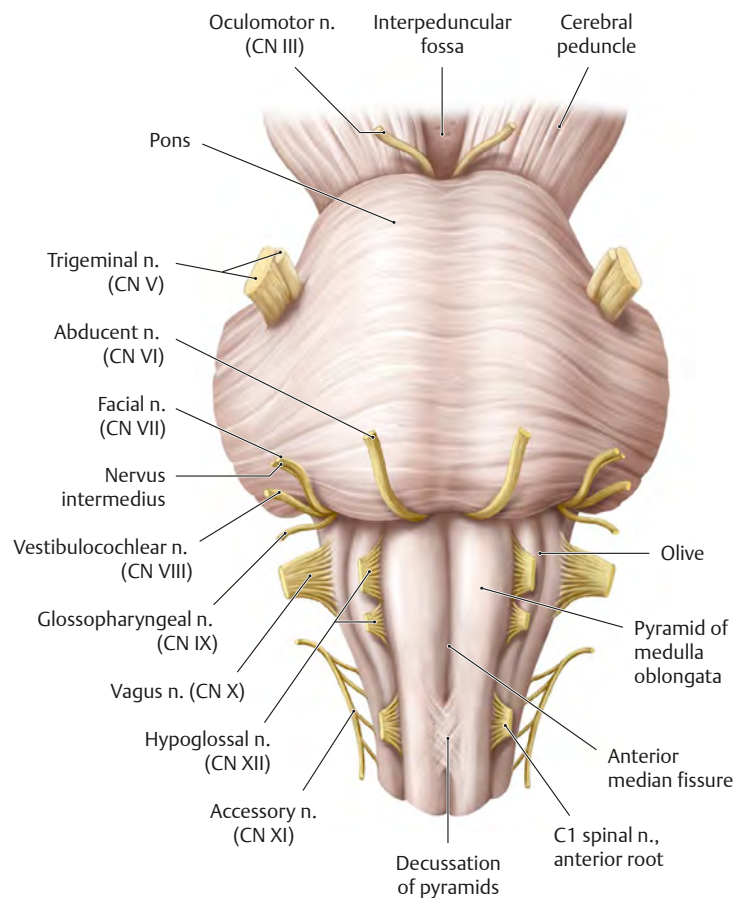
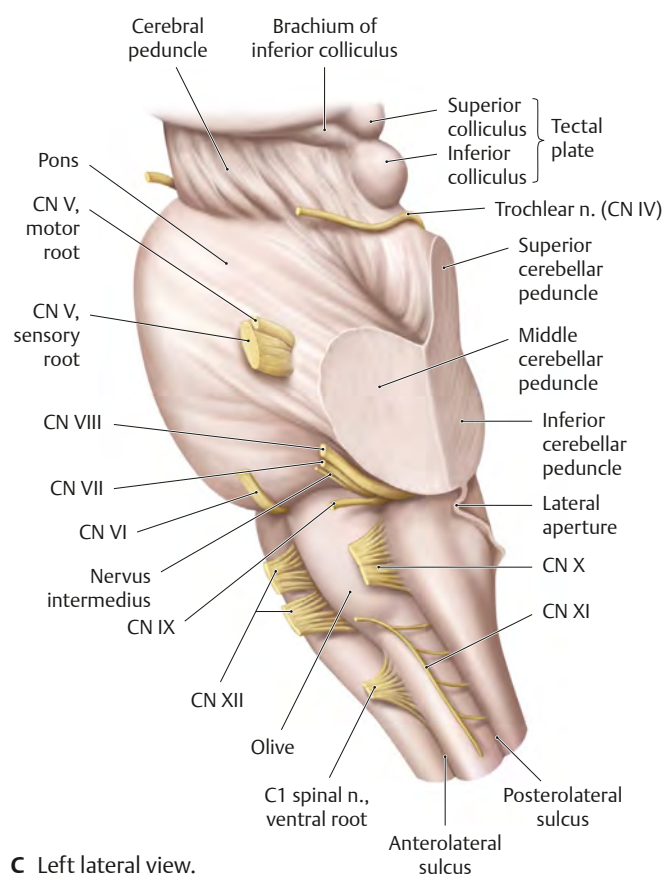
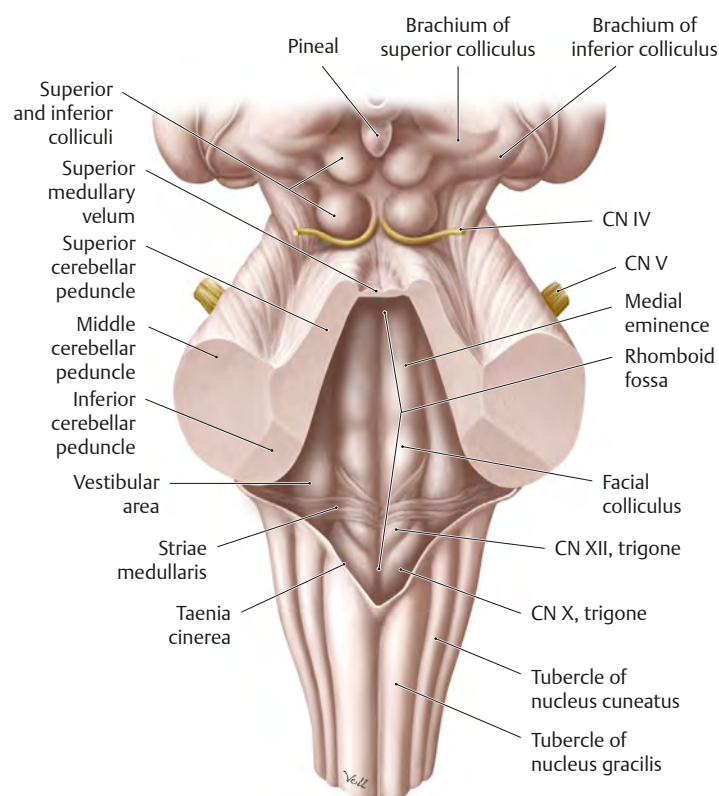
Tracts of afferent (sensory) or efferent (motor) axons enter or leave the cerebellum through cerebellar peduncles. Afferent axons originate in the spinal cord, vestibular organs, inferior olive, and pons. Efferent axons originate in the cerebellar nuclei.



Intermediate parts

Fig. 47.19 Brainstem

The brainstem is the site of emergence and entry of the 10 pairs of true cranial nerves (CN III–XII). See pp. 560–561 for an overview of the cranial nerves and their nuclei.

**A Levels of the brainstem.****B Anterior view.****C Left lateral view.****D Posterior view.**

Ventricles & CSF Spaces

Fig. 47.20 Circulation of cerebrospinal fluid (CSF)

The brain and spinal cord are suspended in CSF. Produced continually in the choroid plexus, CSF occupies the subarachnoid space and ventricles of the brain and drains through arachnoid granulations into the dural

venous sinus system (primarily the superior sagittal sinus) of the cranial cavity. Smaller amounts drain along proximal portions of the spinal nerves into venous plexuses or lymphatic pathways.

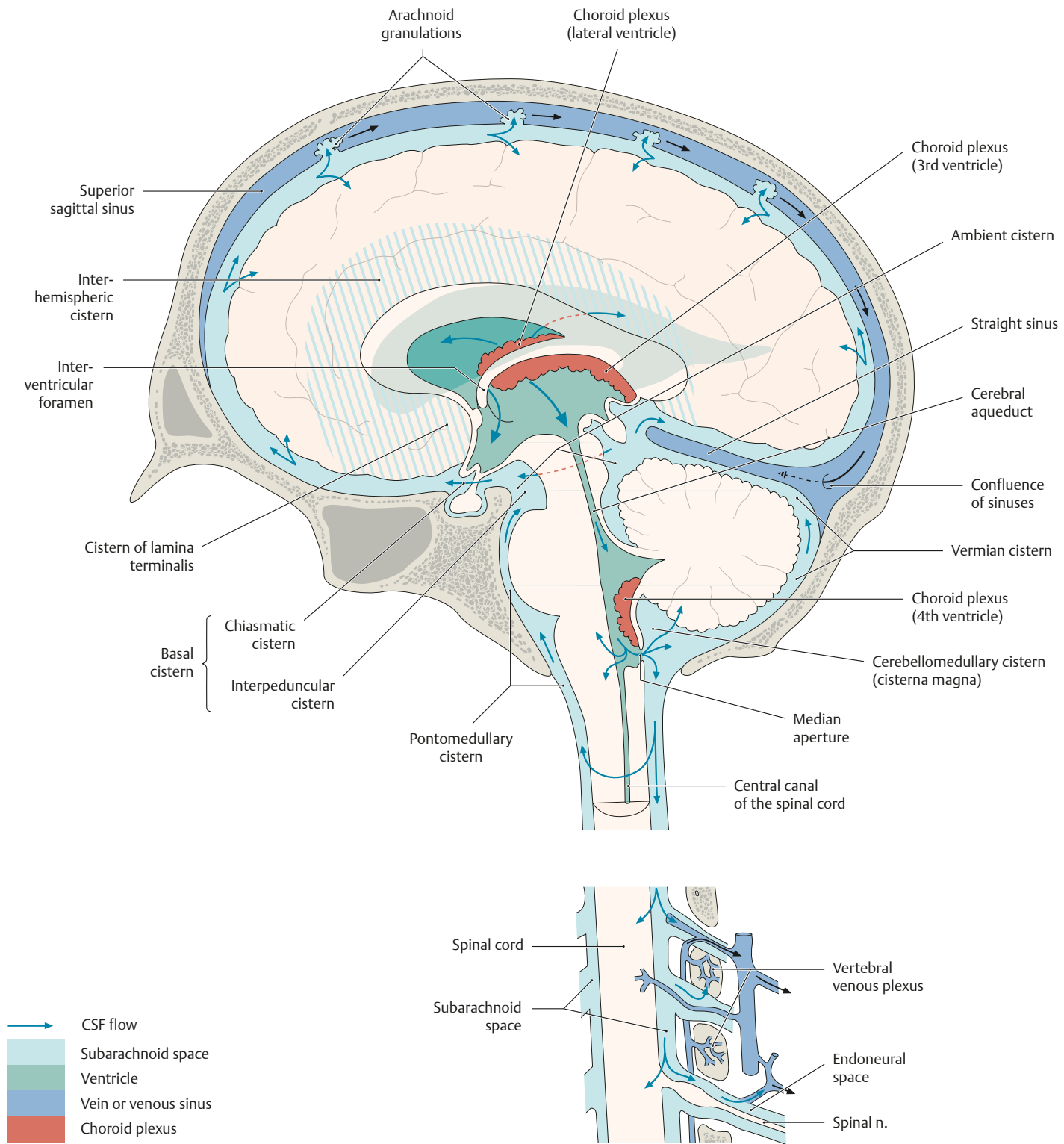
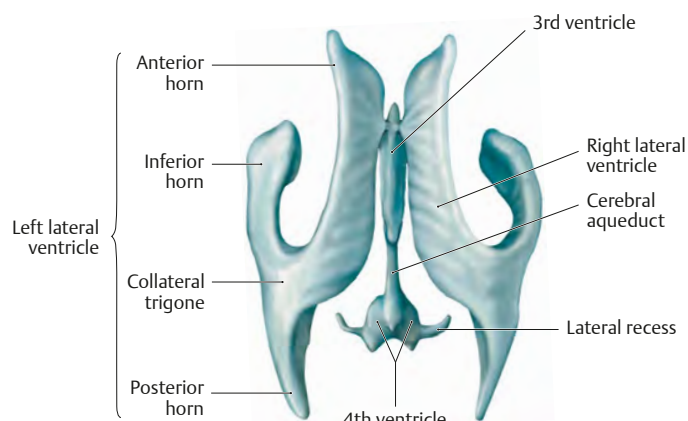
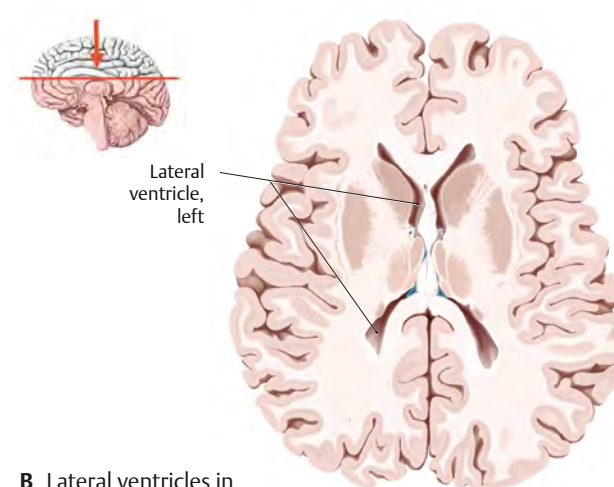
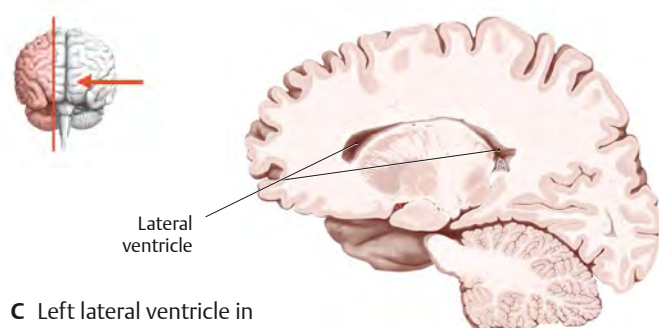
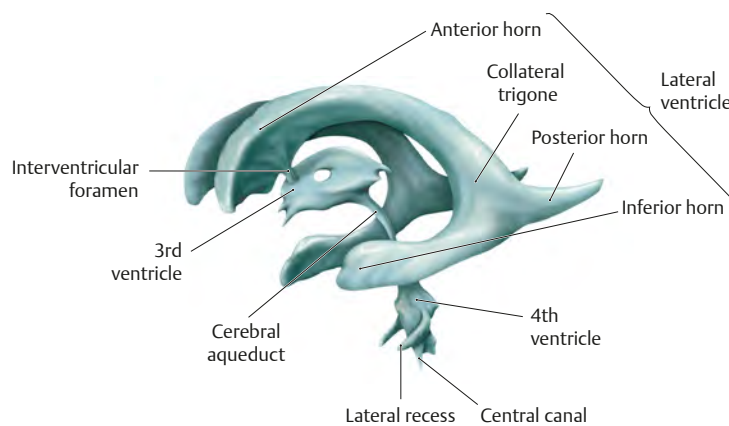
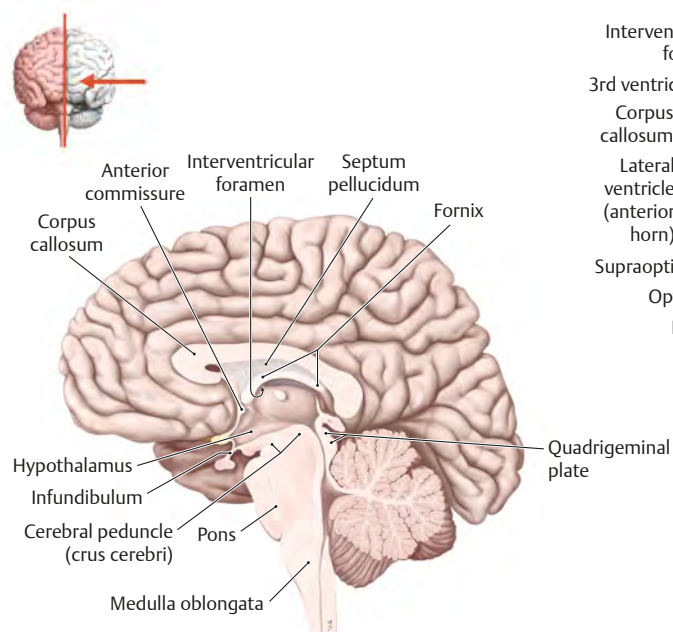
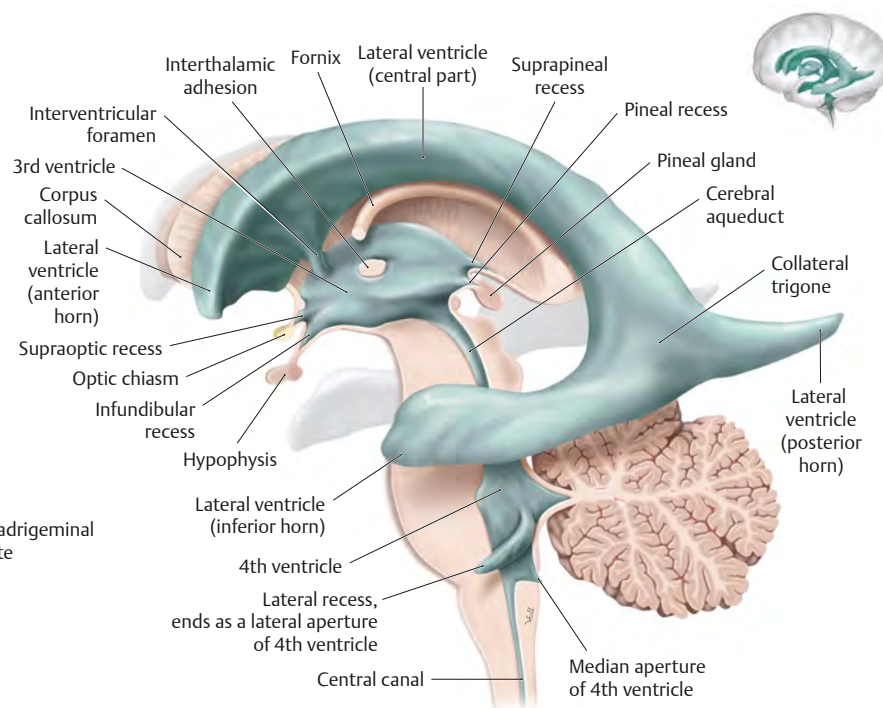


Fig. 47.21 Ventricular system

The ventricular system is a continuation of the central spinal canal into the brain. Cast specimens are used to demonstrate the connections between the four ventricular cavities.

**A Superior view.****B Lateral ventricles in transverse section.****C Left lateral ventricle in parasagittal section.****D Left lateral view.****Fig. 47.22 Ventricular system in situ**

Left lateral view.

**A 3rd and 4th ventricles in midsagittal section.****B Ventricular system with neighboring structures.**

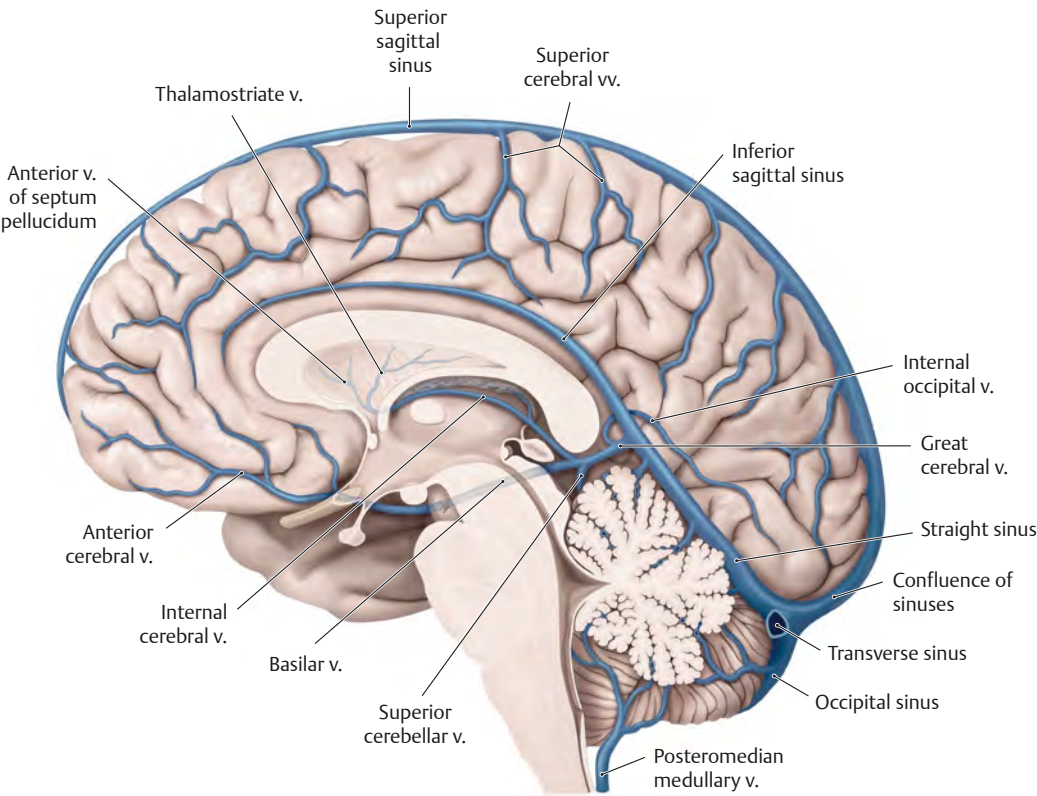
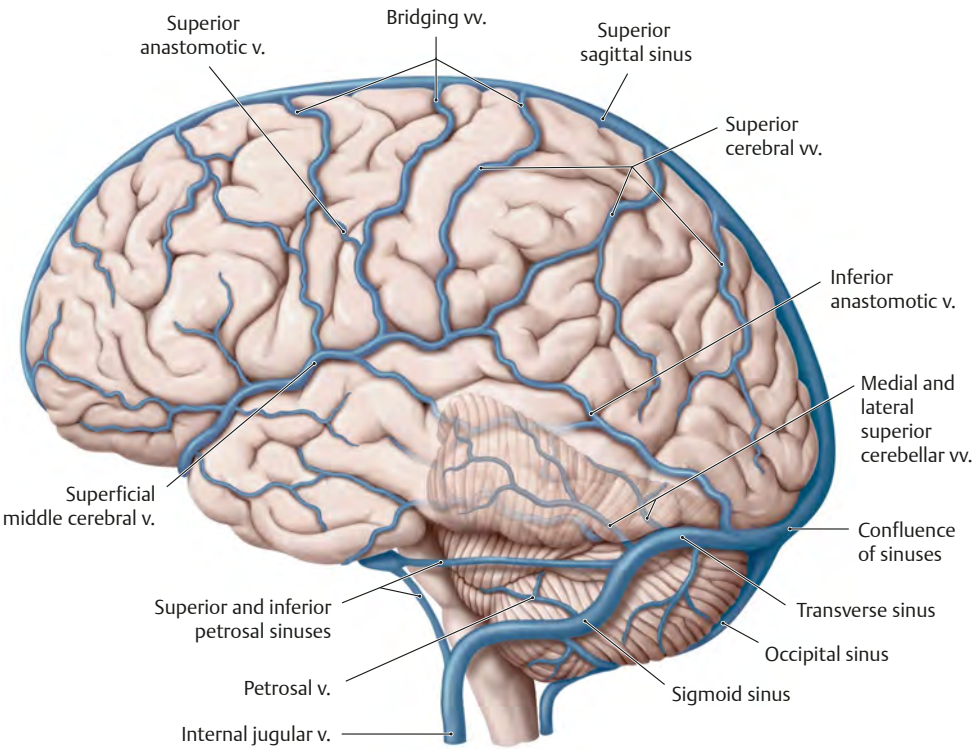
48 Blood Vessels of the Brain

Veins & Venous Sinuses of the Brain

Additional information on the venous sinus system and dural folds of the cranial cavity can be found on pp. 590–593.

Fig. 48.1 Superficial cerebral veins

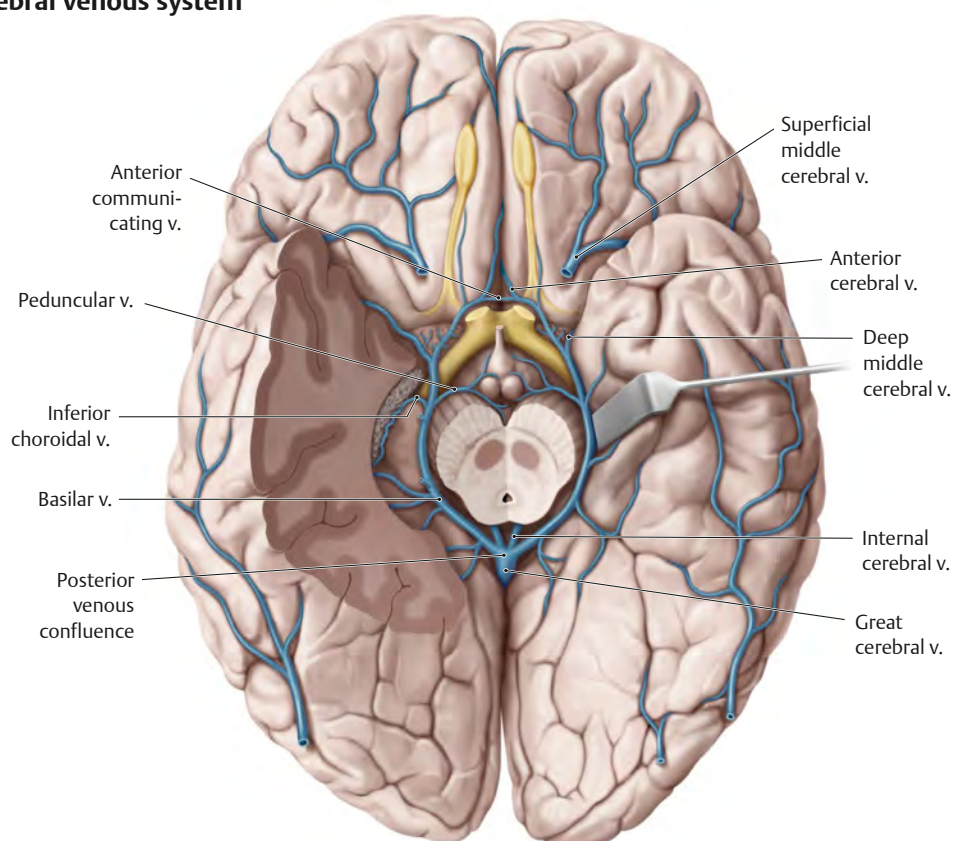
A Left hemisphere, lateral view.



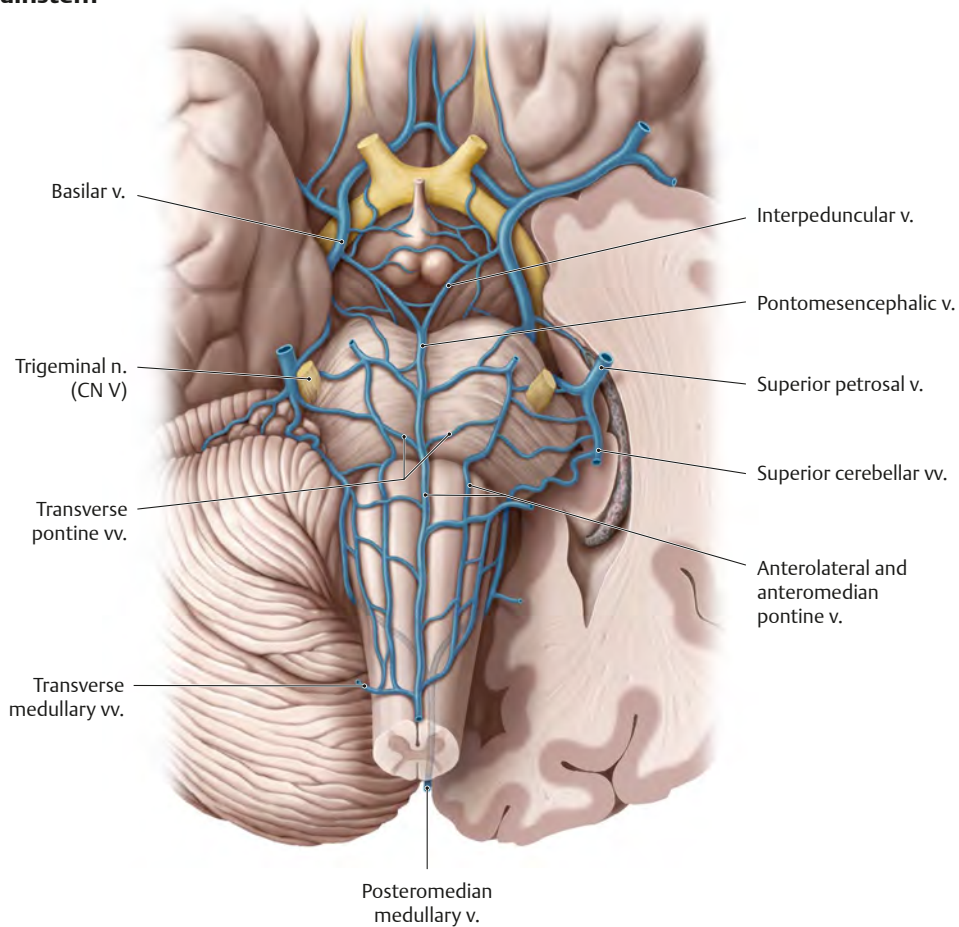
B Right hemisphere, medial view.

Fig. 48.2 Basal cerebral venous system

Basal (inferior) view.

**Fig. 48.3 Veins of the brainstem**

Basal (inferior) view.



Arteries of the Brain

Fig. 48.4 Internal carotid artery

Left lateral view. See p. 582 for details of the internal carotid artery.

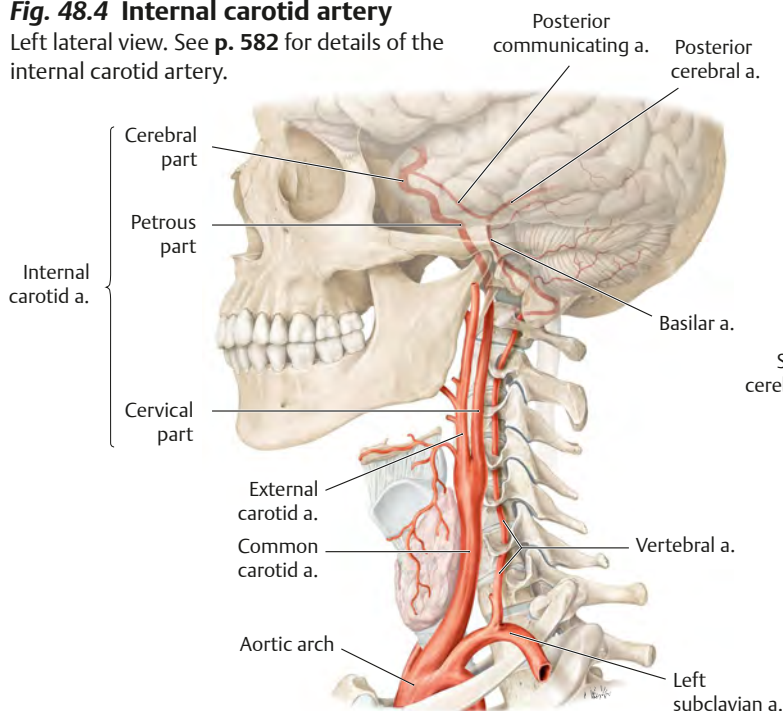


Fig. 48.5 Arteries of the brainstem and cerebellum

Left lateral view.

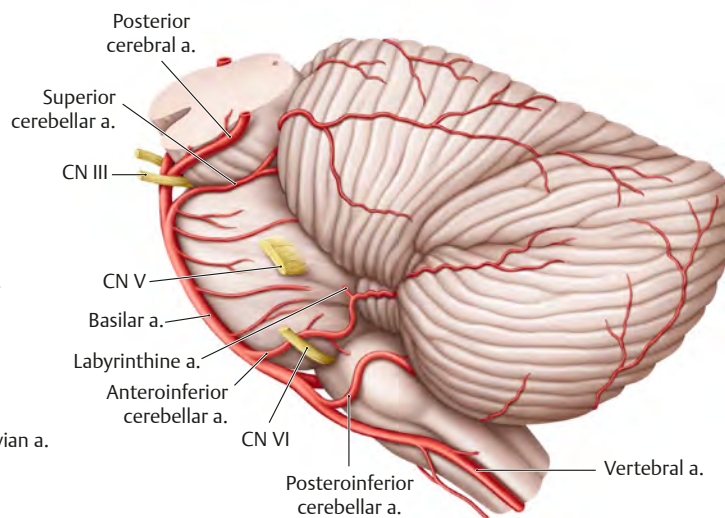


Fig. 48.6 Arteries of the brain

Basal (inferior) view.

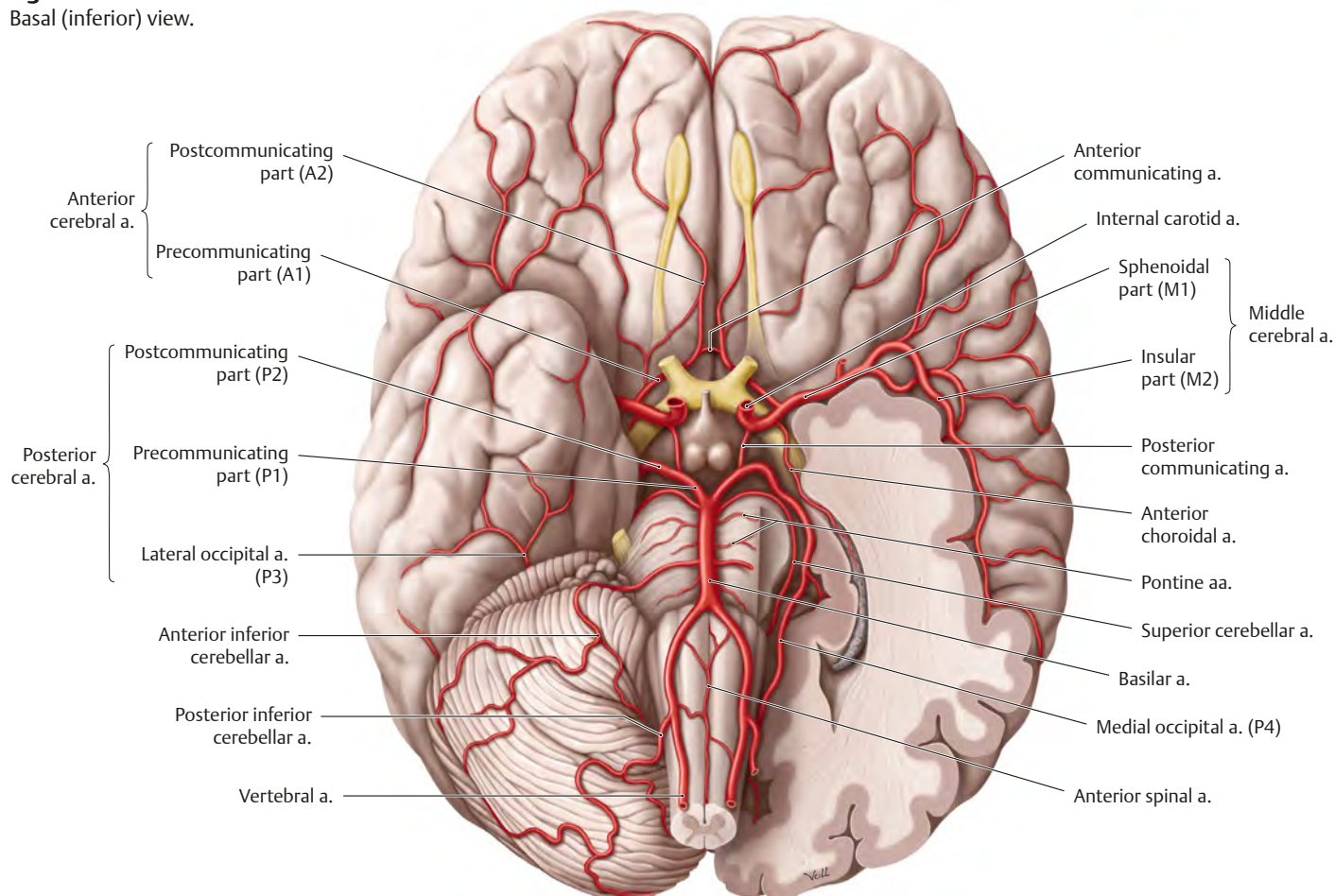
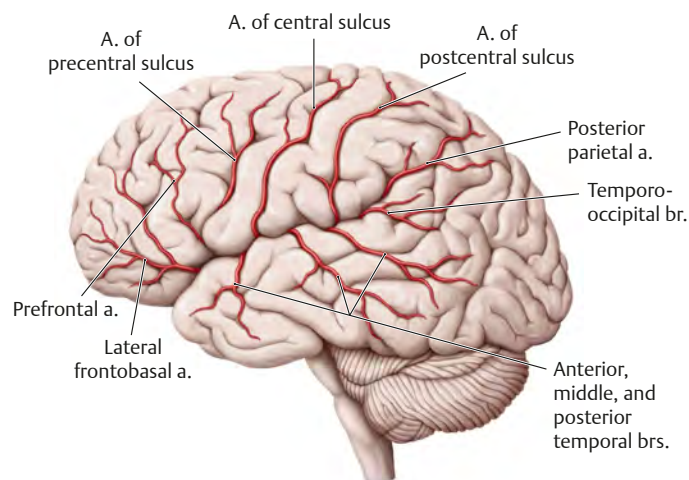
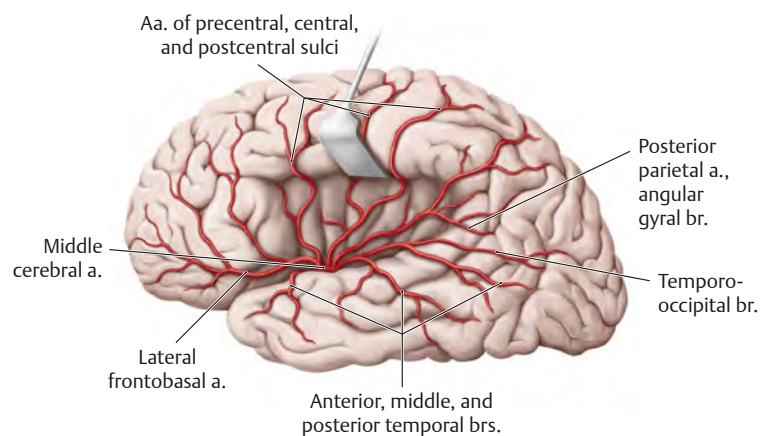
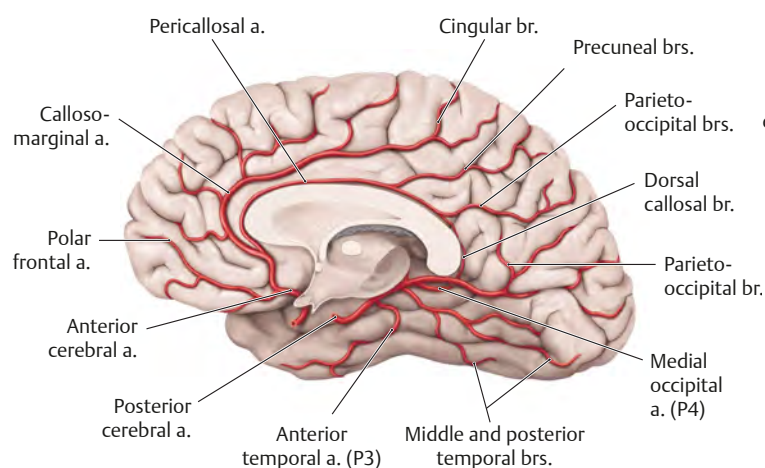
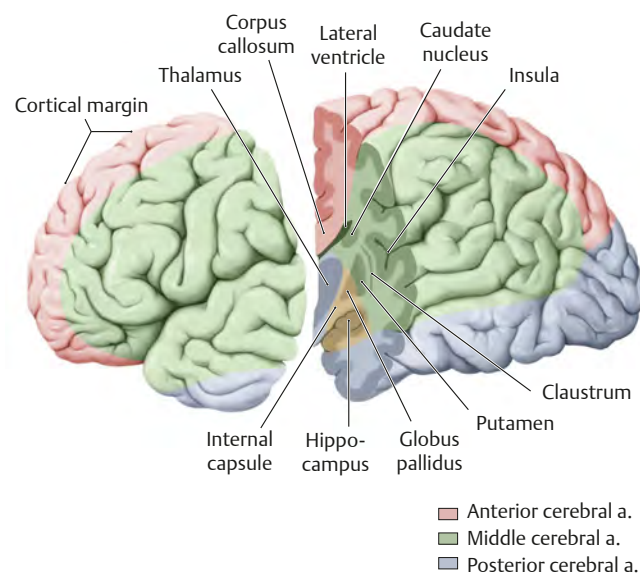
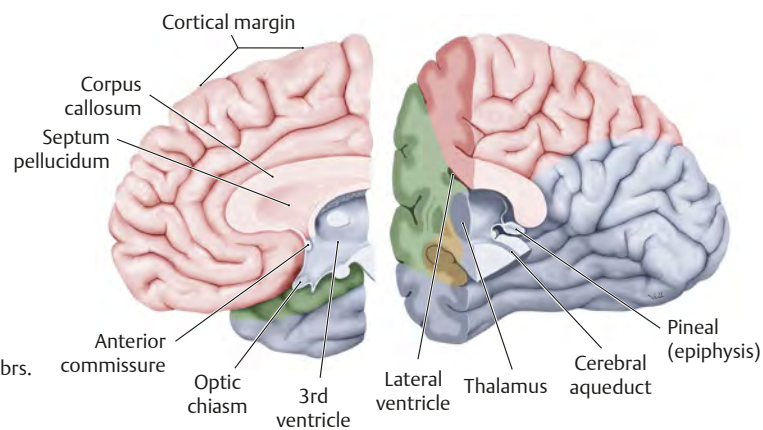


Fig. 48.7 Cerebral arteries**A** Middle cerebral artery. Left hemisphere, lateral view.**B** Middle cerebral artery. Left lateral view with the lateral sulcus retracted.**C** Anterior and posterior cerebral arteries. Right hemisphere, medial view.**Fig. 48.8 Cerebral arteries: Distribution areas**

The central gray and white matter have a complex blood supply (yellow) that includes the anterior choroidal artery.

**A** Left hemisphere, lateral view.**B** Right hemisphere, medial view.

49 Functional Systems

Anatomy & Organization of the Spinal Cord

Fig. 49.1 Anatomy of a spinal cord segment

Three dimensional representation, oblique anterior view from upper left. The gray matter of the spinal cord is found internally, surrounding the central canal in an H-shaped, or butterfly-like, configuration. This is the reverse of what was seen in the brain where the gray matter was

on the external aspect in a cortical configuration. The primary function of the spinal cord is to conduct impulses to and from the brain. To facilitate this, both gray and white matter are organized into longitudinal groupings.

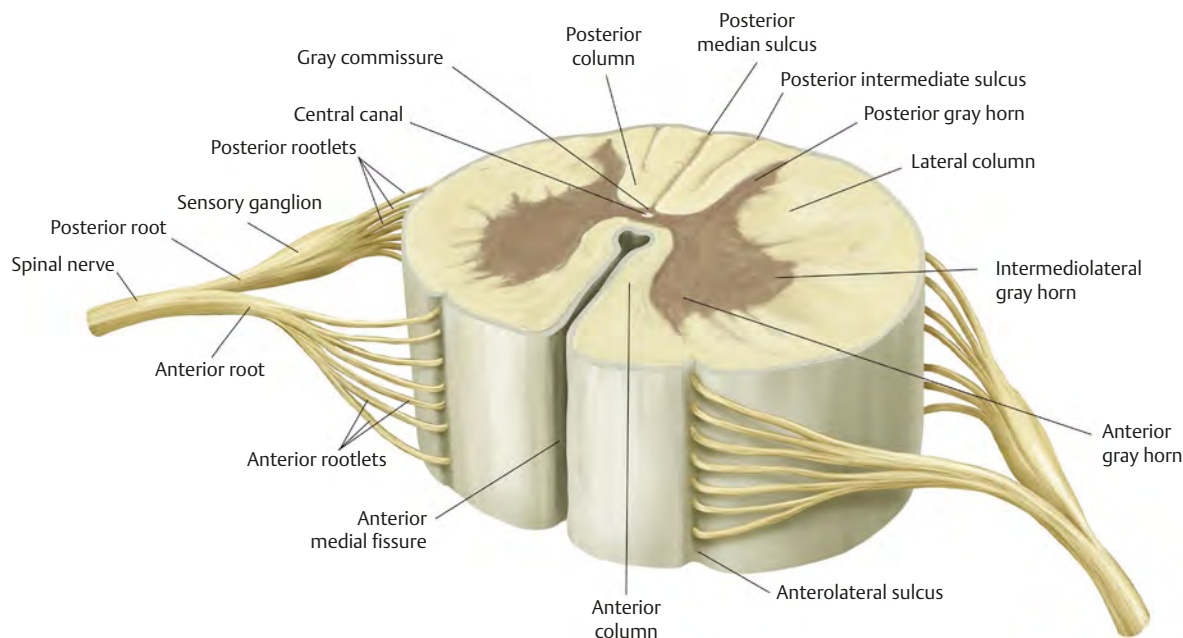


Fig. 49.2 Organization of the gray matter

Left oblique anterosuperior view. The gray matter of the spinal cord is divided into three columns (horns).

- Anterior column (horn): contains motor neurons
- Lateral column (horn): contains sympathetic or parasympathetic (visceromotor) neurons in selected regions
- Posterior column (horn): contains sensory neurons

Sensory (blue) and motor (red) neurons within these columns are clustered in nuclei according to function.

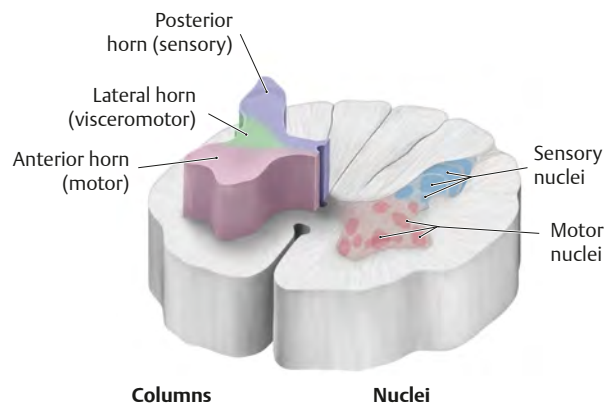


Fig. 49.3 Innervation of muscles

Motor neurons that innervate specific muscles are arranged into vertical columns in the anterior horn of gray matter, the columns themselves can be called nuclei, in a fashion similar to that seen in brainstem motor nuclei. Most muscles (intersegmental muscles) receive innervation from numerous motor nuclei spanning several spinal cord segments. Monosegmental (or indicator) muscles have their motor neurons located entirely within a single spinal cord segment.

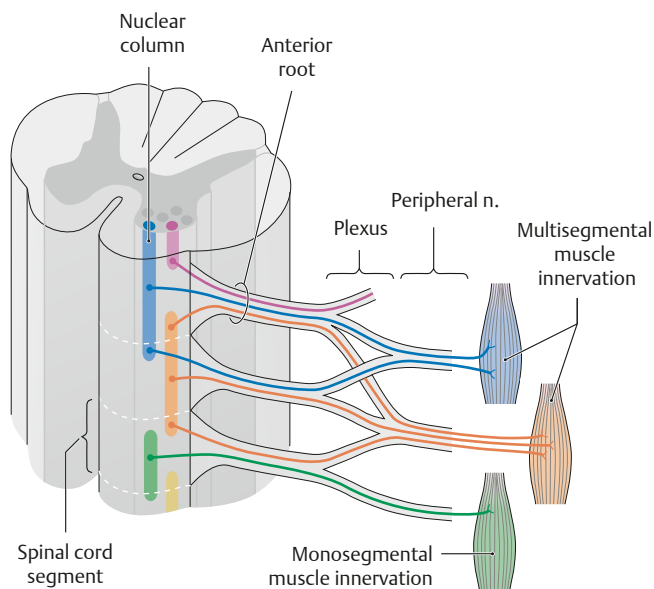
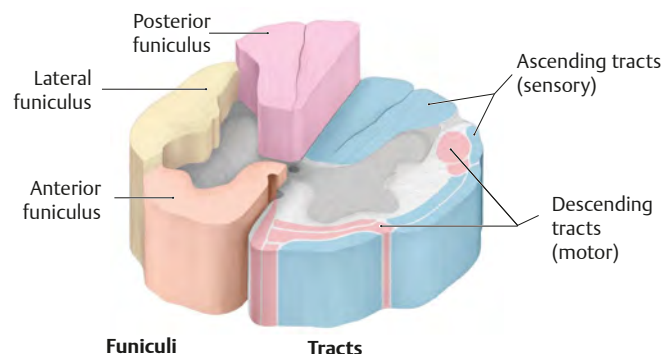
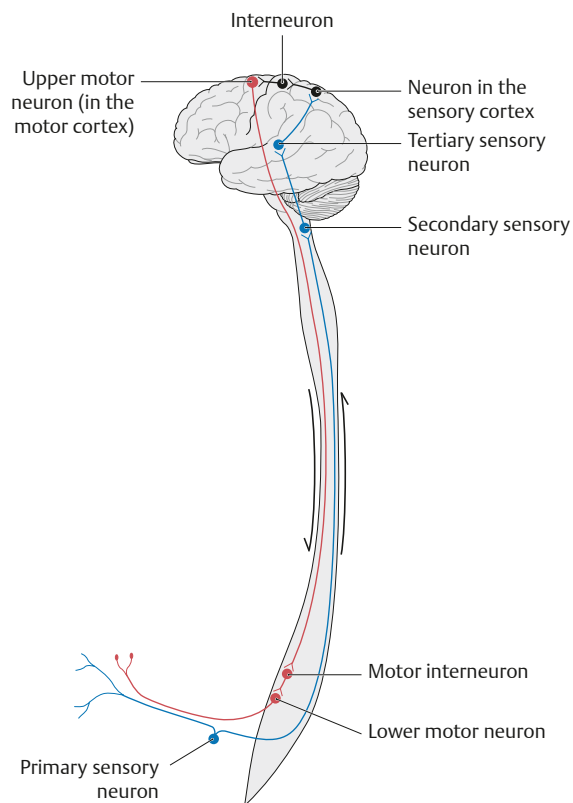


Fig. 49.4 Organization of the white matter

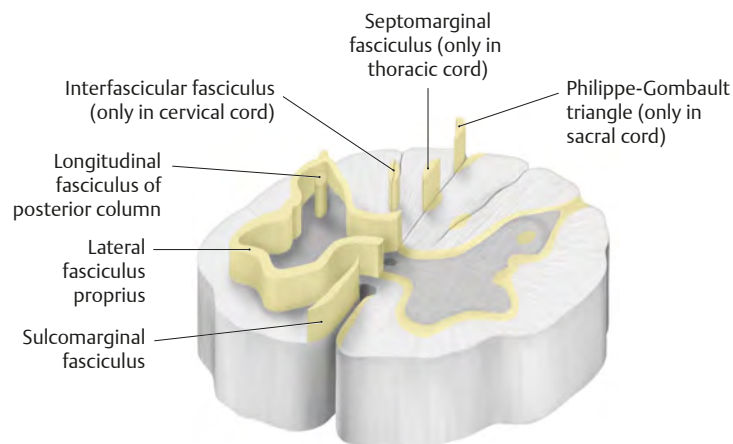
Left oblique anterosuperior view. The gray matter columns partition the white matter analogously into anterior, lateral, and posterior columns or funiculi. The white matter of the spinal cord contains ascending and descending tracts which are the CNS equivalent of peripheral nerves.

**Fig. 49.5 Overview of sensorimotor integration**

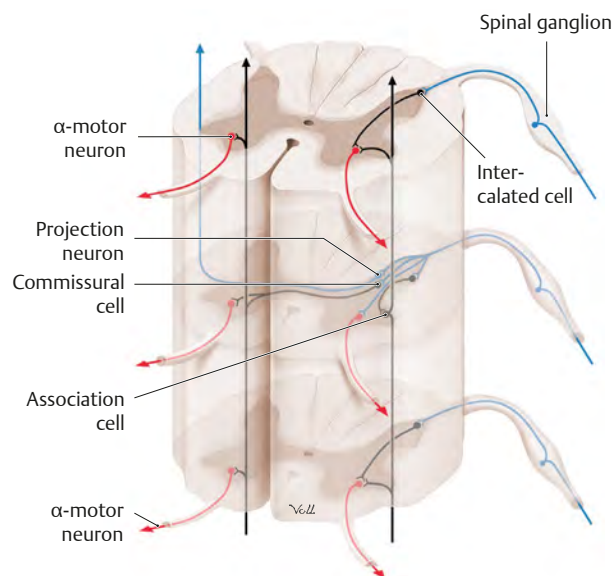
Schematic illustrates the pathway of incoming primary sensory neuron impulses, the axon of which ascends to synapse with the secondary and tertiary sensory neurons in the brainstem and cerebrum ending in a synapse on a neuron in the sensory cortex. An interneuron links this with an upper motor neuron in the motor cortex which then descends through the white matter funiculi of the spinal cord to a motor neuron, which then synapses with a lower motor neuron, the axon of which passes out the spinal nerve to the effector organ.

**Fig. 49.6 Principle intrinsic fascicles of the spinal cord (shaded yellow)**

Left oblique anterosuperior view. The majority of muscles have a multi-segmental mode of innervation that necessitates axons to ascend/descend multiple spinal cord segments to coordinate spinal reflexes. The neurons of these axons originate from interneurons in the gray matter forming intrinsic reflex pathways of the spinal cord. These axons are collected into intrinsic fascicles which are arranged chiefly around the gray matter. These bundles make up the intrinsic circuits of the spinal cord.

**Fig. 49.7 Intrinsic circuits of the spinal cord**

Sensory neurons are shown in blue, motor neurons in red. The neurons of the spinal reflex circuits are in black. These chains of interneurons, which are entirely contained within the spinal cord, comprise the intrinsic circuits of the cord. The axons of these intrinsic circuits pass to adjacent segments in intrinsic fascicles located along the edge of the gray matter.



Sensory & Motor Pathways

Fig. 49.8 Sensory pathways (ascending tracts)

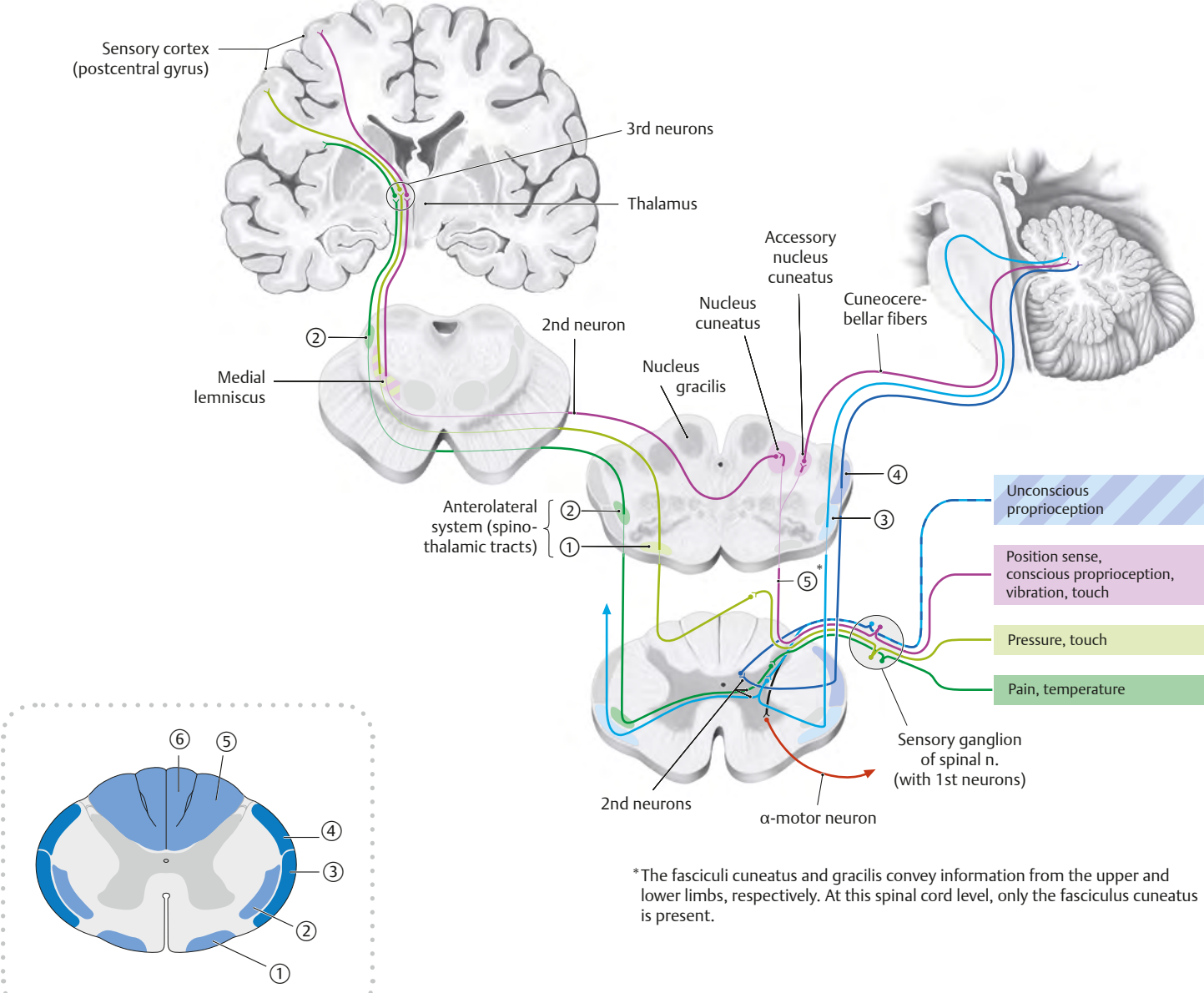
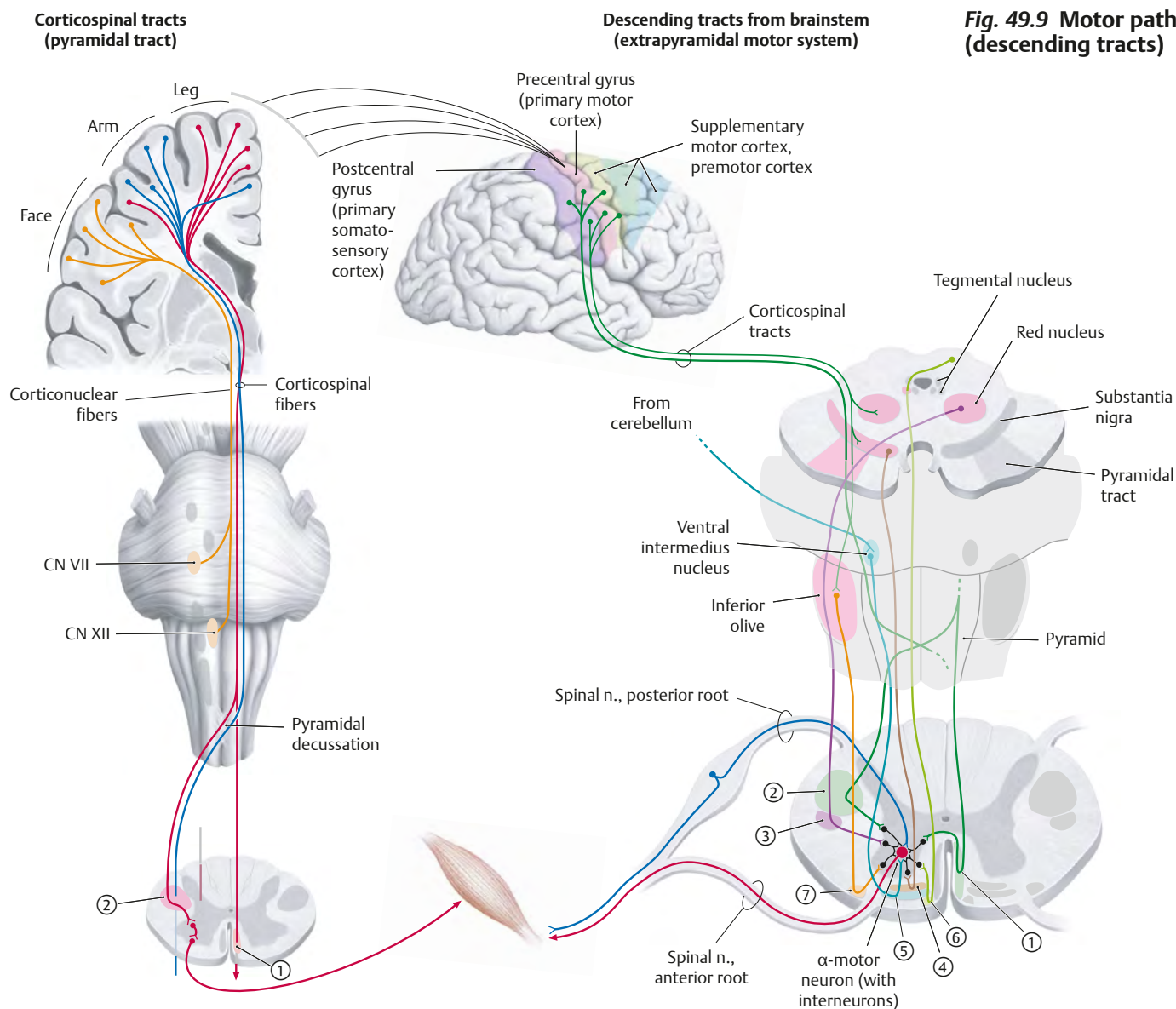
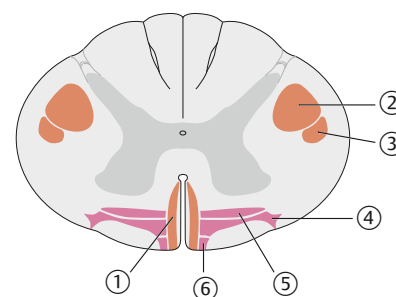


Table 49.1 Sensory pathways (ascending tracts) of the spinal cord				
Tract	Location	Function	Neurons	
① Anterior spino-thalamic tract	Anterior funiculus	Pathway for crude touch and pressure sensation	1st afferent neurons located in spinal ganglia; contain 2nd neurons and cross in the anterior commissure	
② Lateral spino-thalamic tract	Anterior and lateral funiculi	Pathway for pain, temperature, tickle, itch, and sexual sensation		
③ Anterior spino-cerebellar tract	Lateral funiculus	Pathway for unconscious coordination of motor activities (unconscious proprioception, automatic processes, e.g., jogging, riding a bike) to the cerebellum	Projection (2nd) neurons receive proprioceptive signals from 1st afferent fibers originating at the 1st neurons of spinal ganglia	
④ Posterior spino-cerebellar tract	Lateral funiculus			
⑤ Fasciculus cuneatus	Posterior funiculus	Pathway for position sense (conscious proprioception) and fine cutaneous sensation (touch, vibration, fine pressure sense, two-point discrimination)	Conveys information from upper limb (not present below T3)	Cell bodies of 1st neuron located in spinal ganglion; pass uncrossed to the dorsal column nuclei
⑥ Fasciculus gracilis	Posterior funiculus		Conveys information from lower limb	

Fig. 49.9 Motor pathways (descending tracts)**Table 49.2****Descending tracts of the spinal cord**

Tract	Function		
Corticospinal tract (pyramidal tract)	① Anterior corticospinal tract	Most important pathway for voluntary motor function	Originates in the motor cortex <i>Corticospinal fibers</i> to motor nuclei of cranial nerves <i>Corticospinal fibers</i> to motor cells in anterior horn of the spinal cord <i>Corticoreticular fibers</i> to nuclei of the reticular formation
	② Lateral corticospinal tract		
Descending tracts from the brainstem (Extrapyramidal motor system)	③ Rubrospinal tract	Pathway for automatic and learned motor processes (e.g., walking, running, cycling)	
	④ Reticulospinal tract		
	⑤ Vestibulospinal tract		
	⑥ Tectospinal tract		
	⑦ Olivospinal tract		



50 Autonomic Nervous System

Autonomic Nervous System (I): Overview

Fig. 50.1 Autonomic nervous system

The autonomic nervous system is the part of the peripheral nervous system that innervates smooth muscle, cardiac muscle, and glands. It is subdivided into the sympathetic (red) and the parasympathetic (blue) nervous systems, which often act in antagonistic fashion to regulate blood flow, secretions, and organ function. Both the sympathetic and parasympathetic nervous systems have a two-neuron pathway, which is under central nervous system control via an upper motor neuron with its cell body in the hypothalamus. In the sympathetic system, the preganglionic neuron synapses within the ganglia of the sympathetic trunk (paired, one on each side of vertebral column) or on one of the unpaired prevertebral ganglia located at the base of the artery for which the ganglion was named (celiac, superior and inferior mesenteric). Sympathetic postganglionic neurons then either reenter spinal nerves via gray rami communicans and are distributed to their target structure or they reach their target structure by travelling with arteries.

Except in the head, parasympathetic preganglionic neurons synapse in ganglia in the wall of the target organ. Short postganglionic parasympathetic neurons then innervate the organ. In the head there are four parasympathetic ganglia: ciliary, pterygopalatine, submandibular, and otic, which are associated with cranial nerves III, VII, and IX, respectively. These four ganglia are responsible for distributing fibers to smooth muscle within the eye and to the salivary glands and glands of the nasal cavity, paranasal sinuses, hard and soft palate, and pharynx. Both sympathetic and parasympathetic preganglionic neurons secrete acetylcholine, which acts upon nicotinic receptors in the ganglia. Sympathetic postganglionic neurons secrete norepinephrine, which acts upon adrenoceptors (α or β) in target tissues. Parasympathetic postganglionic neurons secrete acetylcholine, which acts upon muscarinic receptors in target tissues.

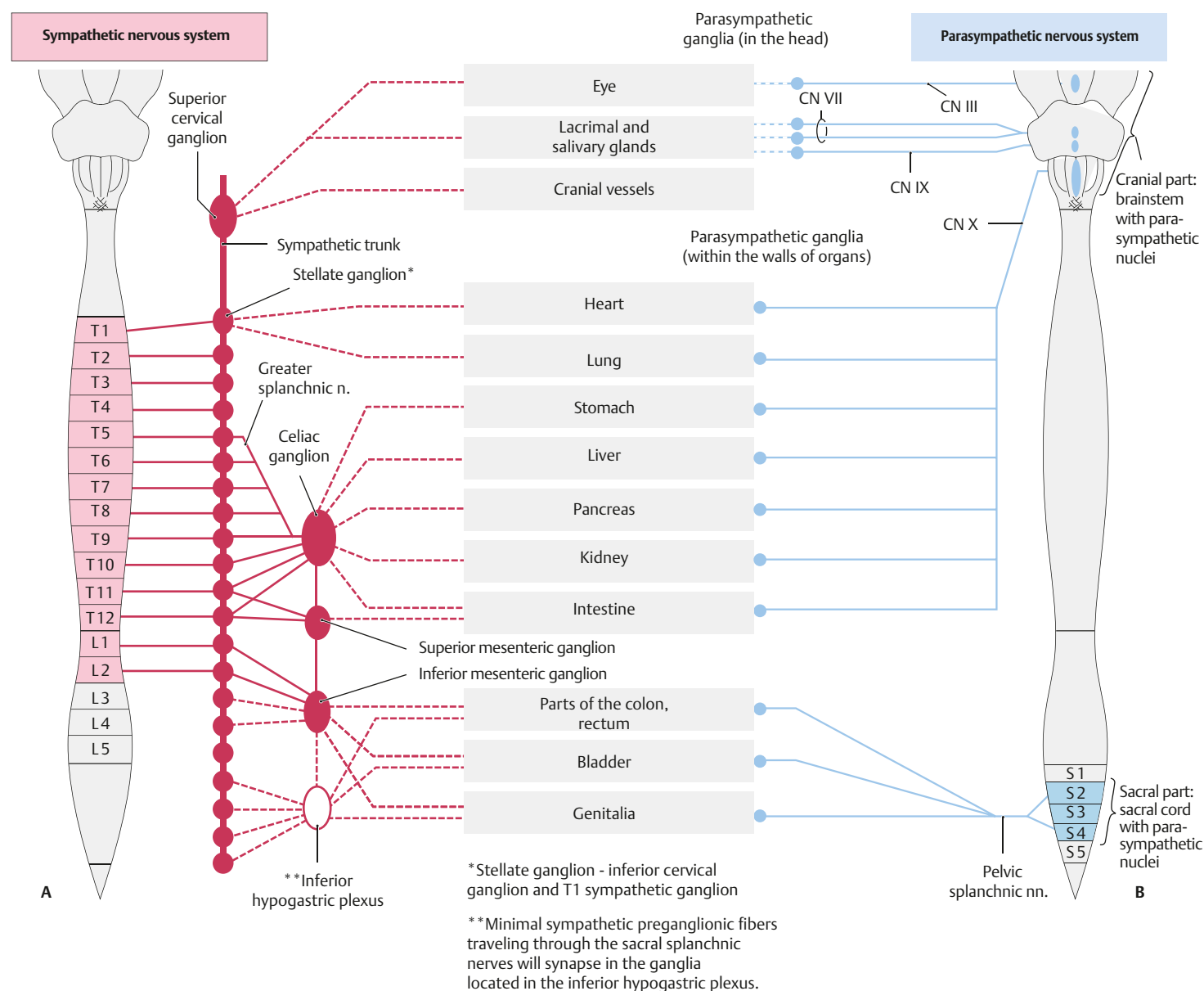


Table 50.1

Parasympathetic pathways

Neuron	Location of cell body
Upper motor neuron	Hypothalamus: The cell bodies of parasympathetic upper motor neurons are located in the hypothalamus. Their axons descend via white matter tracts to synapse with the lower motor neuron in the brainstem and sacral spinal cord (S2–S4).
Preganglionic neuron (lower motor neuron)	The parasympathetic nervous system is divided into two parts (cranial and sacral), based on the location of the preganglionic parasympathetic neurons.
	Brainstem cranial nerve nuclei: The axons of these secondary neurons leave the CNS as the motor root of cranial nn. III, VII, IX, and X. Spinal cord (S2–S4): The axons of the sacral parasympathetics originate from the S2–S4 spinal segments in a region of the spinal cord gray matter similar to that of the lateral horns where the sympathetic division arises from. These axons initially travel through the S2–S4 anterior roots before continuing within the S2–S4 anterior rami. The axons then pass through pelvic splanchnic nerves that arise from the S2–S4 anterior rami before reaching the inferior hypogastric plexus, which then distributes the axons to the pelvic and hindgut structures.
Postganglionic neuron	Cranial nerve parasympathetic ganglia: The parasympathetic cranial nn. of the head each have at least one ganglion: • CN III: Ciliary ganglion • CN VII: Pterygopalatine ganglion and submandibular ganglion • CN IX: Otic ganglion • CN X: Small unnamed (intramural) ganglia close to target structures
Distribution of postganglionic fibers	Parasympathetic fibers course with other fiber types to their targets. In the head, the postganglionic fibers from the pterygopalatine ganglion (CN VII) and otic ganglion (CN IX) are distributed via branches of the trigeminal n. (CN V). Postganglionic fibers from the ciliary ganglion (CN III) course with sympathetic and sensory fibers in the short ciliary nn. (preganglionic fibers travel with the somatomotor fibers of CN III). In the thorax, abdomen, and pelvis, preganglionic parasympathetic fibers from CN X and the pelvic splanchnic nn. combine with postganglionic sympathetic fibers to form plexuses (e.g., cardiac, pulmonary, esophageal).

Table 50.2

Sympathetic pathways

Neuron	Location of cell body
Upper motor neuron	Hypothalamus: The cell bodies of sympathetic upper motor neurons are located in the hypothalamus. Their axons descend via white matter tracts to synapse with the lower motor neuron in the lateral horn of the spinal cord (T1–L2).
Preganglionic neuron (lower motor neuron)	Intermediolateral gray horn of spinal cord (T1–L2): The lateral horn is the middle portion of the gray matter of the spinal cord, situated between the anterior and posterior horns. It contains exclusively autonomic (sympathetic) neurons. The axons of these neurons leave the CNS as the motor root of the spinal nn. and enter the paravertebral ganglia via the white rami communicans (myelinated).
Preganglionic neurons in paravertebral ganglia	All preganglionic sympathetic neurons enter the sympathetic chain. There they may synapse in a chain ganglion or ascend or descend to synapse. Preganglionic sympathetic neurons synapse in one of two places, yielding two types of sympathetic ganglia. Synapse in the paravertebral ganglia Pass without synapsing through the sympathetic ganglia. These fibers travel in the thoracic, lumbar, and sacral splanchnic nn. to synapse in the prevertebral ganglia.
Postganglionic neuron	Paravertebral ganglia: These ganglia form the sympathetic nerve trunks that flank the spinal cord. Postganglionic axons leave the sympathetic trunk via the gray rami communicans (unmyelinated). Prevertebral ganglia: Associated with peripheral plexuses, which spread along the abdominal aorta. There are three primary prevertebral ganglia: • Celiac ganglion • Superior mesenteric ganglion • Inferior mesenteric ganglion
Distribution of postganglionic fibers	Postganglionic fibers are distributed in two ways: 1. Spinal nerves: Postganglionic neurons may re-enter the spinal nn. via the gray rami communicans. These sympathetic neurons induce constriction of blood vessels of the skin and dilate the blood vessels of skeletal muscles, sweat glands, and arrector pili (muscle fibers attached to hair follicles, “goose bumps”). 2. Arteries and ducts: Nerve plexuses may form along existing structures. Postganglionic sympathetic fibers may travel with arteries to target structures. Viscera are innervated by this method (e.g., sympathetic innervation concerning vasoconstriction, bronchial dilatation, glandular secretions, pupillary dilatation, smooth muscle contraction).

Autonomic Nervous System (II)

Fig. 50.2 Typical spinal nerve

All spinal nerves arising from the spinal cord contain somatic sensory (or afferent, from body wall) and somatic motor (or efferent, to body wall) fibers. Sensory fibers come from the posterior (back) region via the posterior ramus and anterolateral regions of the body wall via the anterior ramus of the spinal nerve. The somatic sensory fibers approach the spinal cord via the posterior root. The cell bodies for these fibers lie in the sensory (spinal/dorsal root) ganglion. They synapse with sensory

neurons in the posterior horn of gray matter within the spinal cord sending the majority to the brain for interpretation. Somatic motor fibers have their neurons in the anterior horn of gray matter and send their fibers to the spinal n. via the anterior root. This pattern of somatic innervation occurs in all spinal nerves from C1 through S5, whether they are involved in a plexus or not.

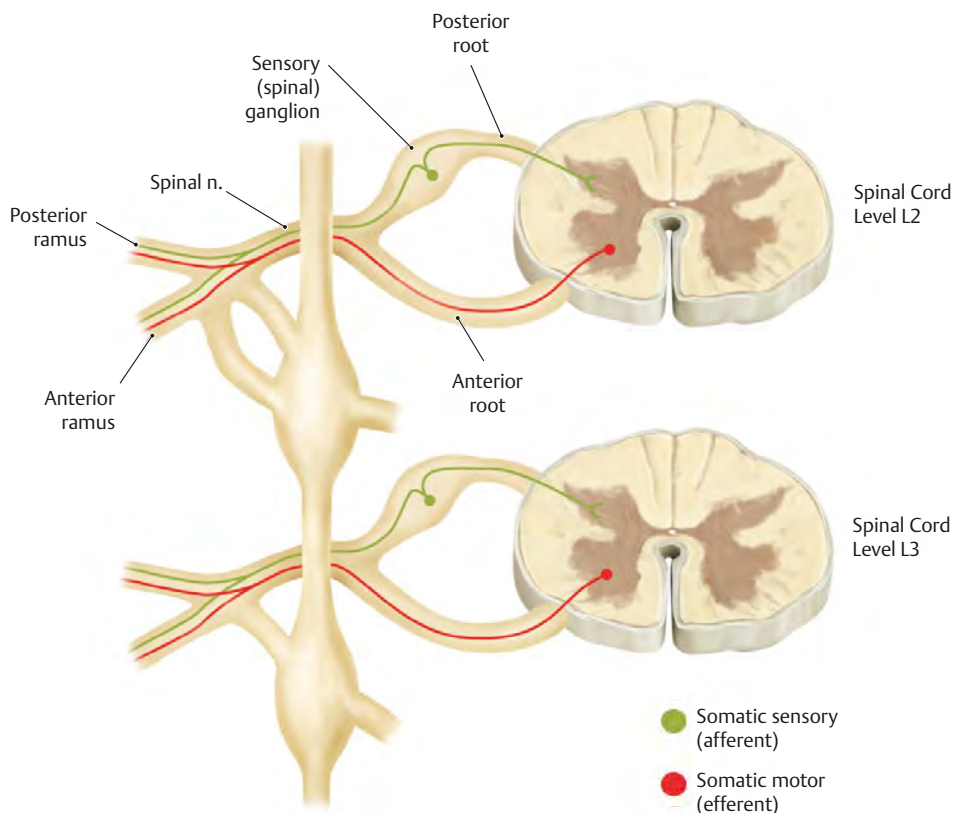


Fig. 50.3 ANS Circuitry

Body wall dermatomes also require sympathetic fibers to contract smooth muscle and cause glands in the dermatome to secrete. Preganglionic sympathetic fibers (purple) arise from cell bodies in the intermediolateral gray horn of the spinal cord. They exit the spinal cord via the outgoing/efferent (anterior) root—along with the somatic motor (efferent) fibers—and enter the spinal nerve. The smooth muscle of the body wall requires innervation by postganglionic sympathetic fibers so the preganglionic fiber looks for the closest synapse site—the paravertebral sympathetic ganglia—found in a chain-like arrangement on either side of the vertebral column. Each ganglion is connected to the spinal n. by communicating branches—the rami communicans. The white ramus communicans is found most lateral and conveys the preganglionic (myelinated = white) sympathetic fiber to the ganglion. Once in the paravertebral ganglion one of two things can happen:

- The preganglionic sympathetic fiber can synapse in the ganglion and the postganglionic sympathetic fiber (orange) passes along the gray ramus communicans (unmyelinated) back to the spinal n. Now postganglionic sympathetic fibers can be distributed to structures

in the dermatome via the anterior and posterior rami—along with somatic motor and sensory fibers.

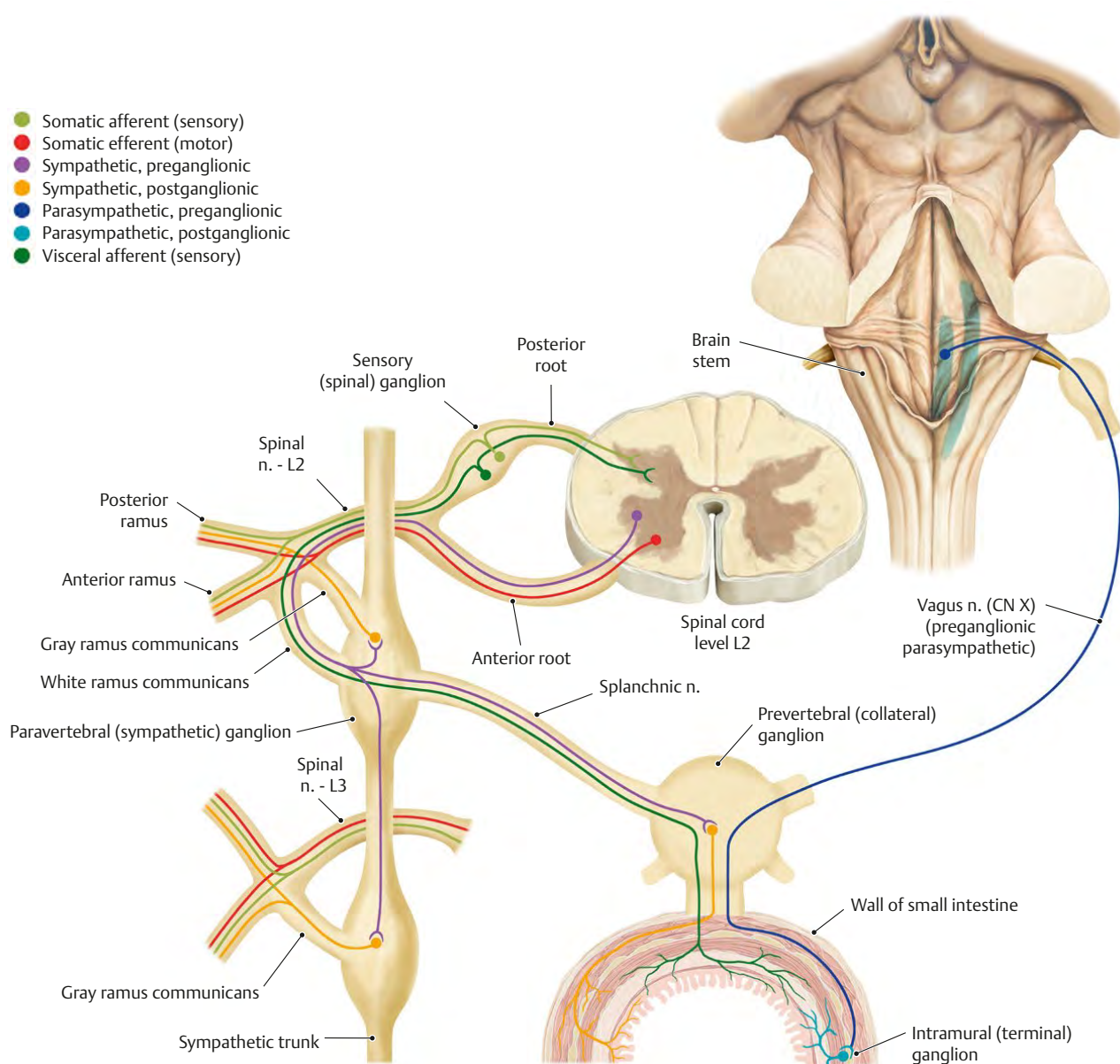
- The preganglionic fiber can run up or down the sympathetic trunk to synapse in an upper or lower paravertebral ganglion. This is especially important as the source of sympathetic innervation is limited to spinal cord levels T1 to L2. This figure depicts sympathetic innervation from the last spinal cord segment to contain it (L2) descending along the sympathetic trunk to the paravertebral ganglion at L3. It synapses here and the postganglionic sympathetic fiber exits into the spinal nerve of L3. Note that there is only a gray ramus communicans at this level as white rami communicans are input fibers (T1–L2), while the gray are output fibers above and below T1 and L2. Therefore, there are more gray rami than white rami. Both anterior and posterior rami now contain postganglionic sympathetic fibers distributed to the dermatome of L3 along with the typical somatic sensory and motor fibers of each vertebral level.

Now that the body wall has been supplied with postganglionic sympathetic innervation, we'll turn our attention to the viscera. In the

third option for preganglionic sympathetic fibers entering a prevertebral ganglion, the fibers pass through the paravertebral ganglion at that level without synapsing and pass into a splanchnic n. to synapse in one of 3 primary prevertebral (or collateral) ganglia found in the abdomen along the anterior surface of the aorta at the base of one of the three main visceral branches (celiac a., superior mesenteric a., and inferior mesenteric a.). The postganglionic sympathetic fibers (orange) are distributed by following arterial branches to the viscera where they decrease the activity of the glands and peristalsis, constrict sphincters, and vasoconstrict the blood vessels.

The body wall does not receive any parasympathetic innervation. Dilation of the blood vessel walls occurs as the postganglionic sympathetics stop firing to cause vasoconstriction. However, the intricate control of movement of the wall of the intestine, or secretion of the glands within its wall, does require the antagonistic input of the parasympathetic division. Parasympathetic innervation to the viscera of the thorax and much of the abdomen (to the mid transverse colon) is supplied by the vagus n. (dark blue). The vagus n. sends branches to the various sympathetic prevertebral ganglia of the abdomen but they do not synapse there. They pass through, following the branches of the blood vessel to the wall of the organs supplied. There they synapse in

tiny parasympathetic (intramural) ganglion within the wall of the organ. The postganglionic parasympathetic fibers (light blue) are therefore extremely short. The remainder of the abdominal and pelvic viscera receive their parasympathetic supply in a similar fashion but from preganglionic parasympathetic fibers from spinal cord levels S2-4. Viscera also exhibit pain, relayed back to the CNS as visceral afferents (dark green). Note that the visceral afferent fibers follow the pathway of the sympathetic pre- and postganglionic fibers back from the viscera. They pass through the prevertebral ganglion (without synapsing), and then back along the splanchnic n. and through the paravertebral ganglion (again, without synapsing). From there they travel along the white ramus communicans (as visceral afferent fibers, they are also myelinated) and follow the posterior root back to the sensory ganglion where the cell body is found interspersed amongst those for the body wall. They finally synapse in the posterior horn of gray matter in the spinal cord amongst the somatic afferents also synapsing there. This is the basis for referred pain as the brain finds it difficult to distinguish visceral pain from somatic pain as the latter outnumber the former very significantly. Therefore, pain from internal organs is often referred to sites on the body wall.



51 Sectional & Radiographic Anatomy

Sectional Anatomy of the Nervous System

Fig. 51.1 Sagittal section through the midline of the brain

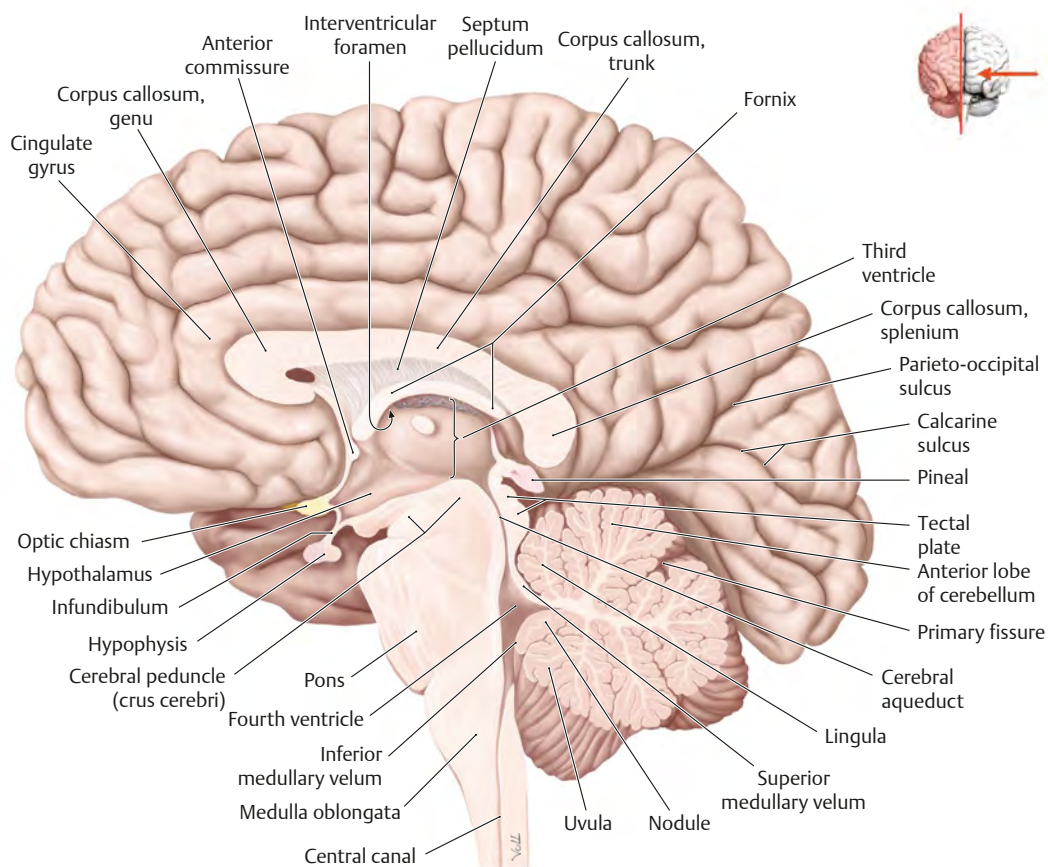


Fig. 51.2 Frontal section through the brain I

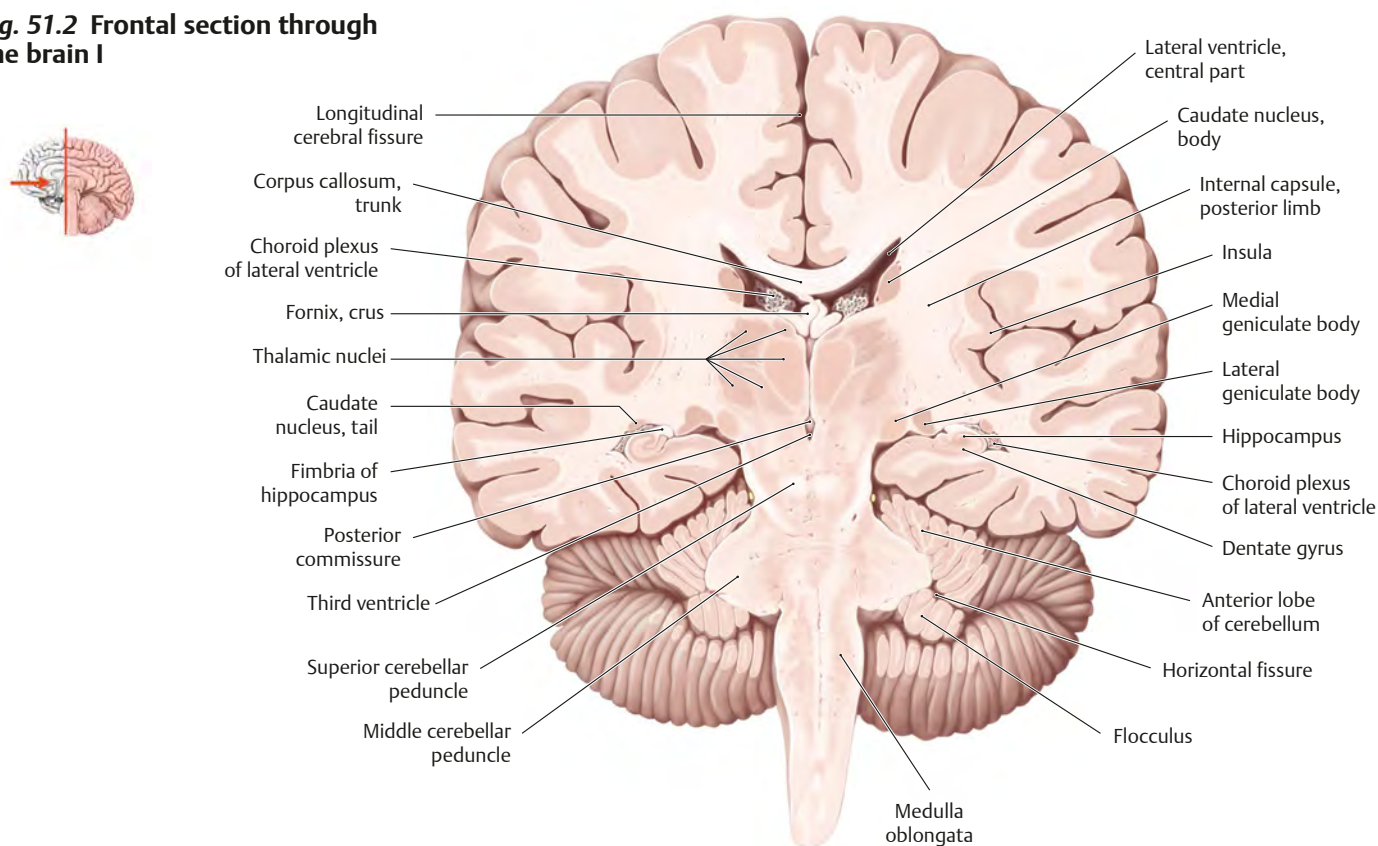


Fig. 51.3 Frontal section through the brain II

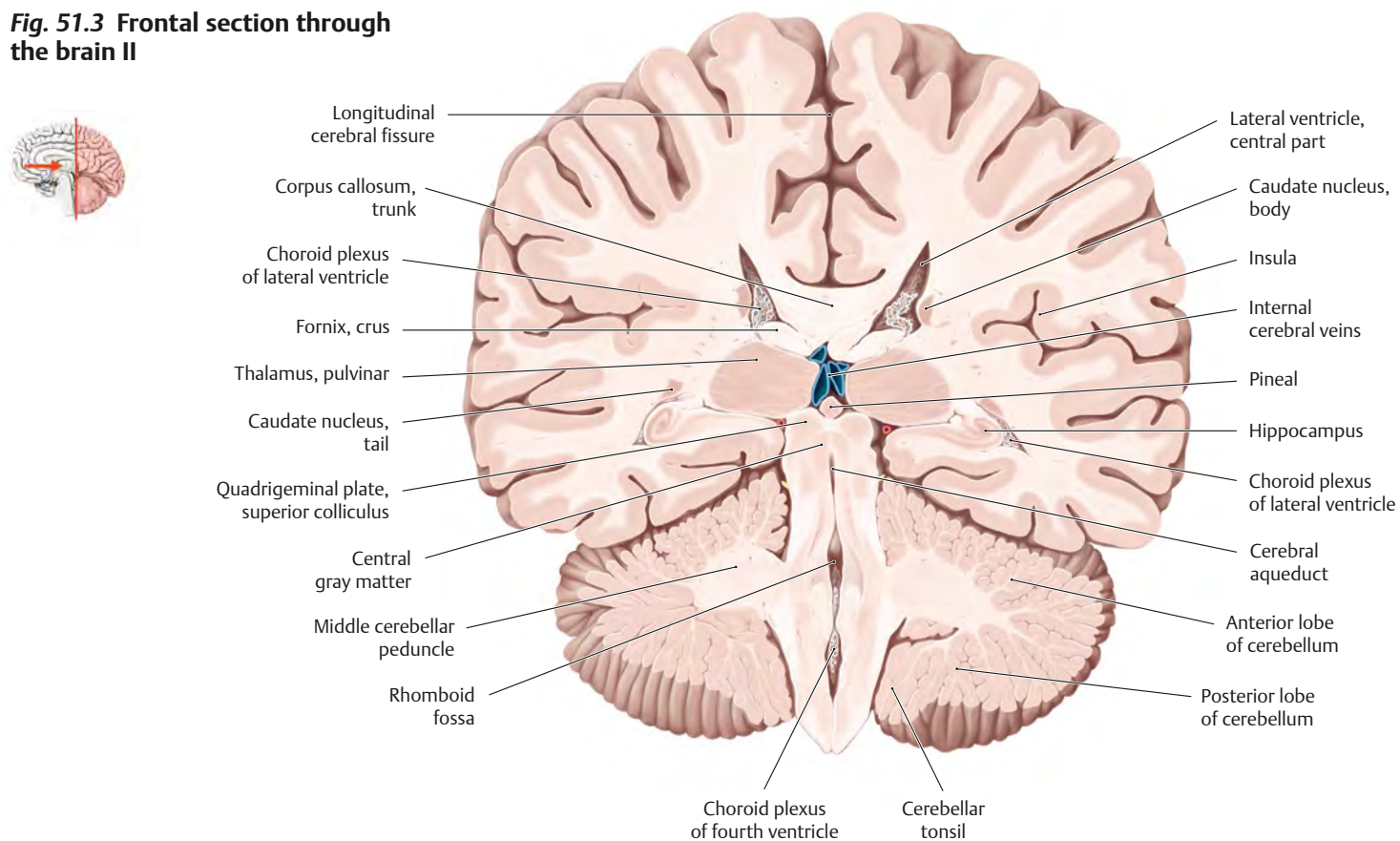
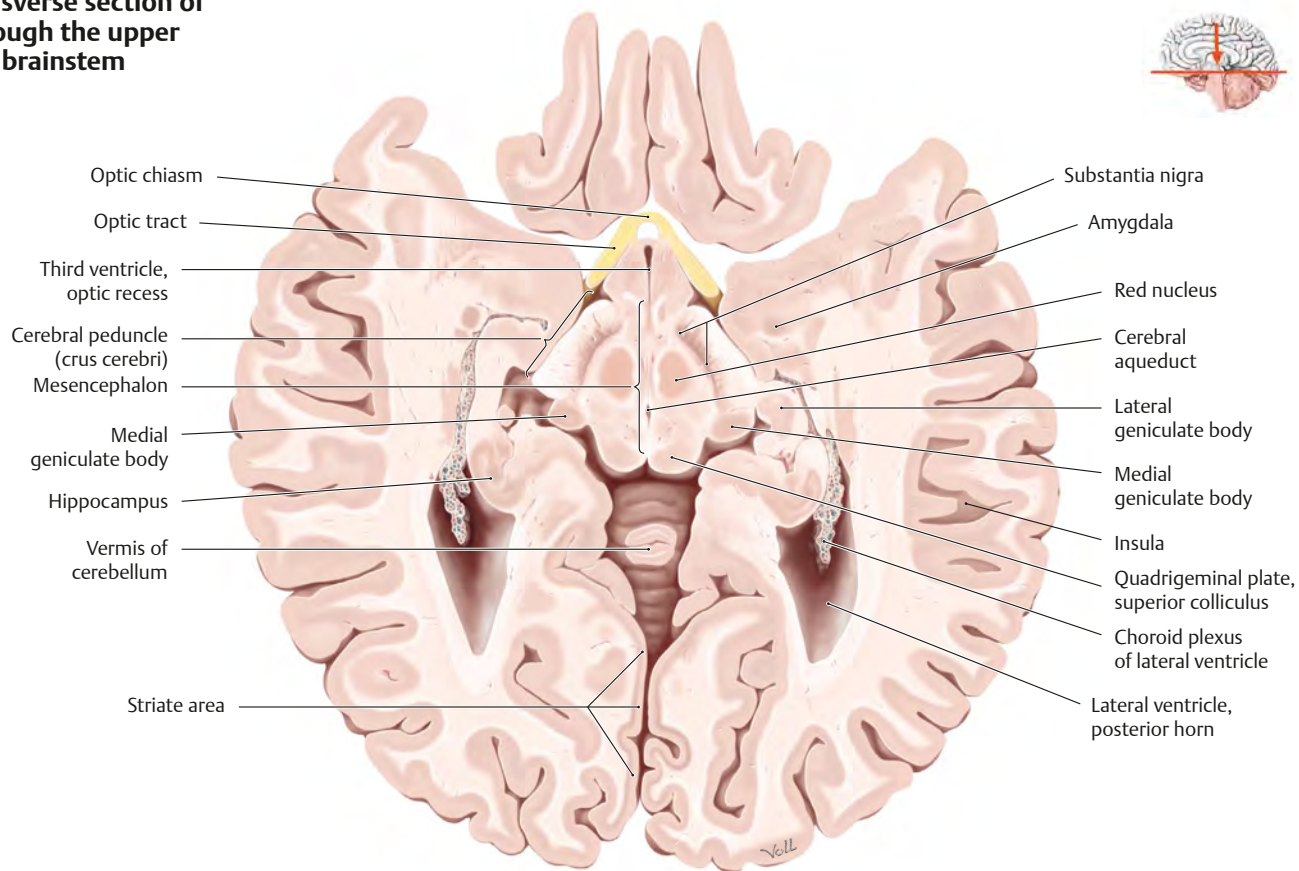


Fig. 51.4 Transverse section of the brain through the upper region of the brainstem



Radiographic Anatomy of the Nervous System

Additional radiological images of the blood supply to the brain can be found on **p. 671**.

Fig. 51.5 MRI of the brain

Midsagittal section, left lateral view.
(Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)

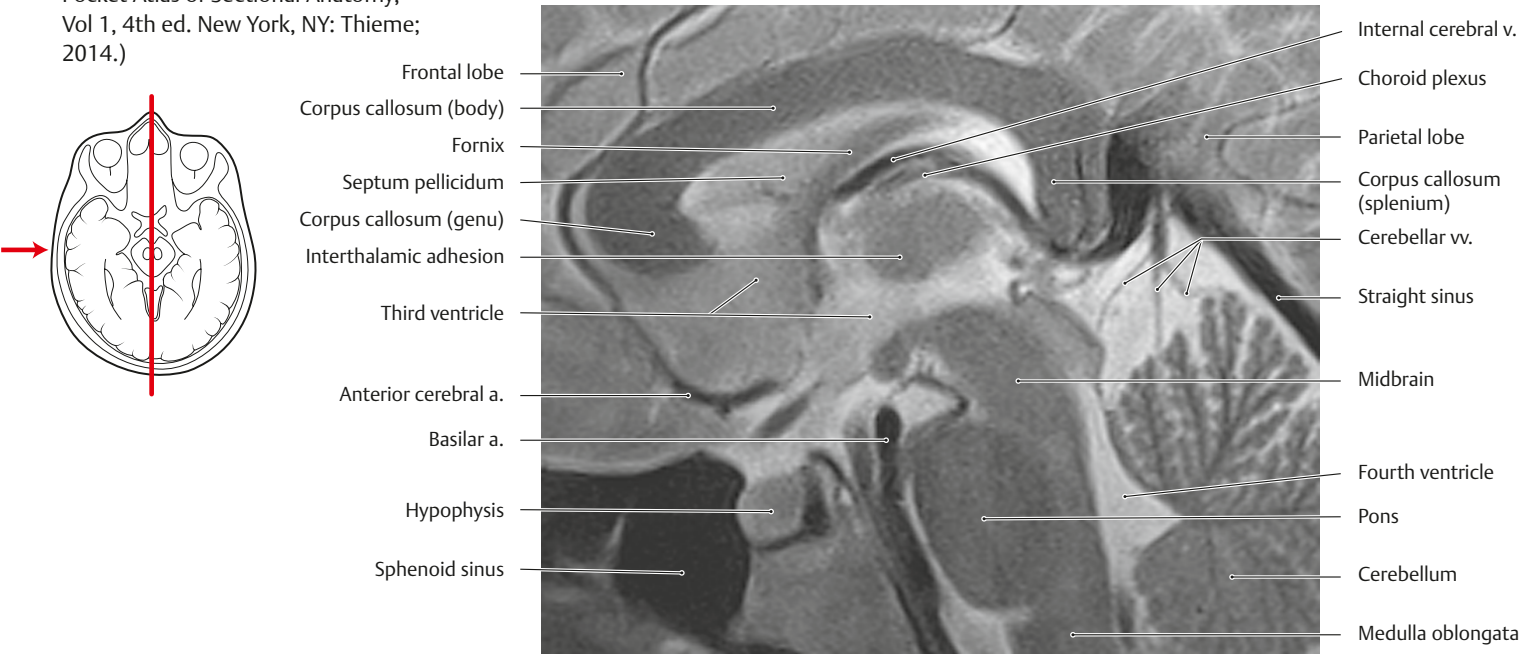


Fig. 51.6 MRI of the brain

Transverse (axial) section through the cerebral hemispheres, inferior view.
(Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)

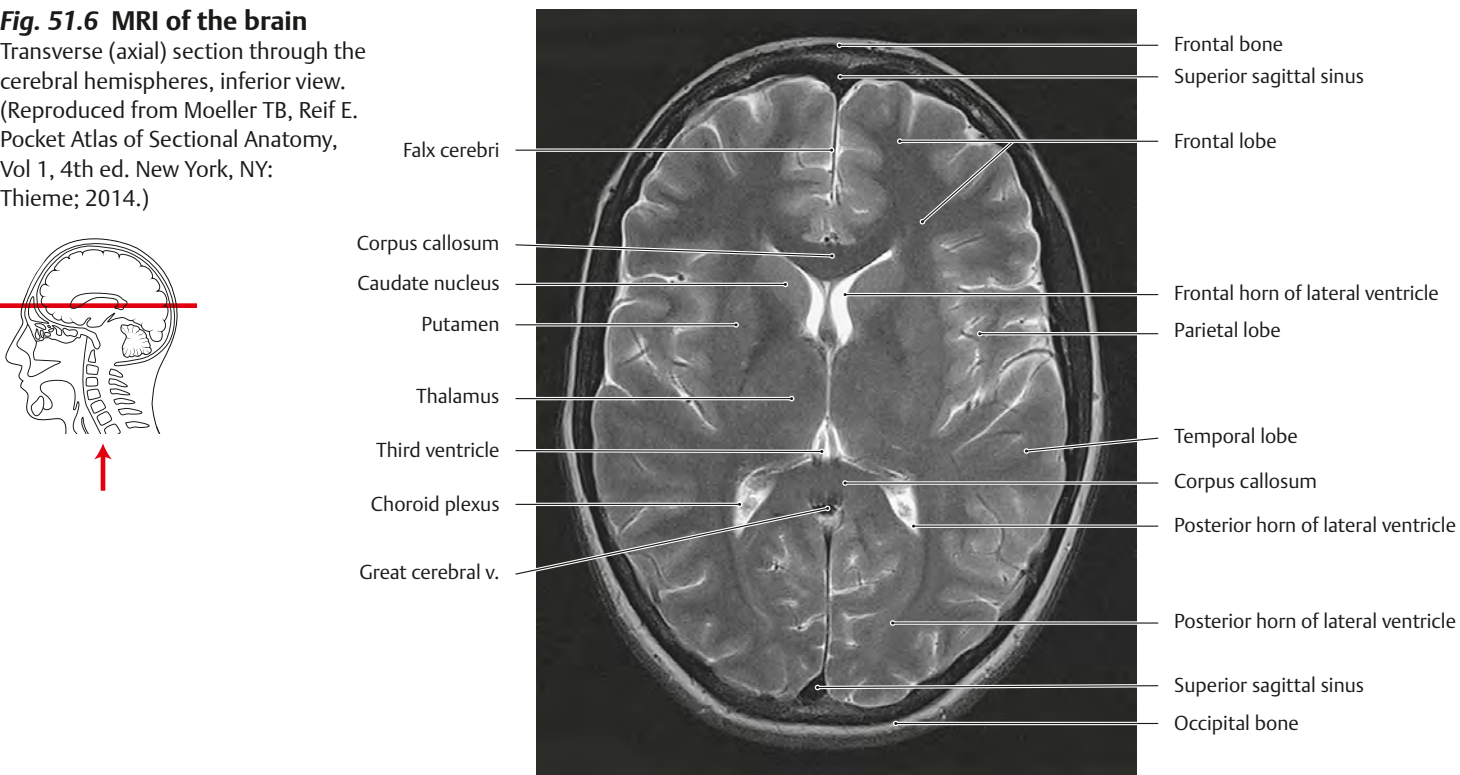
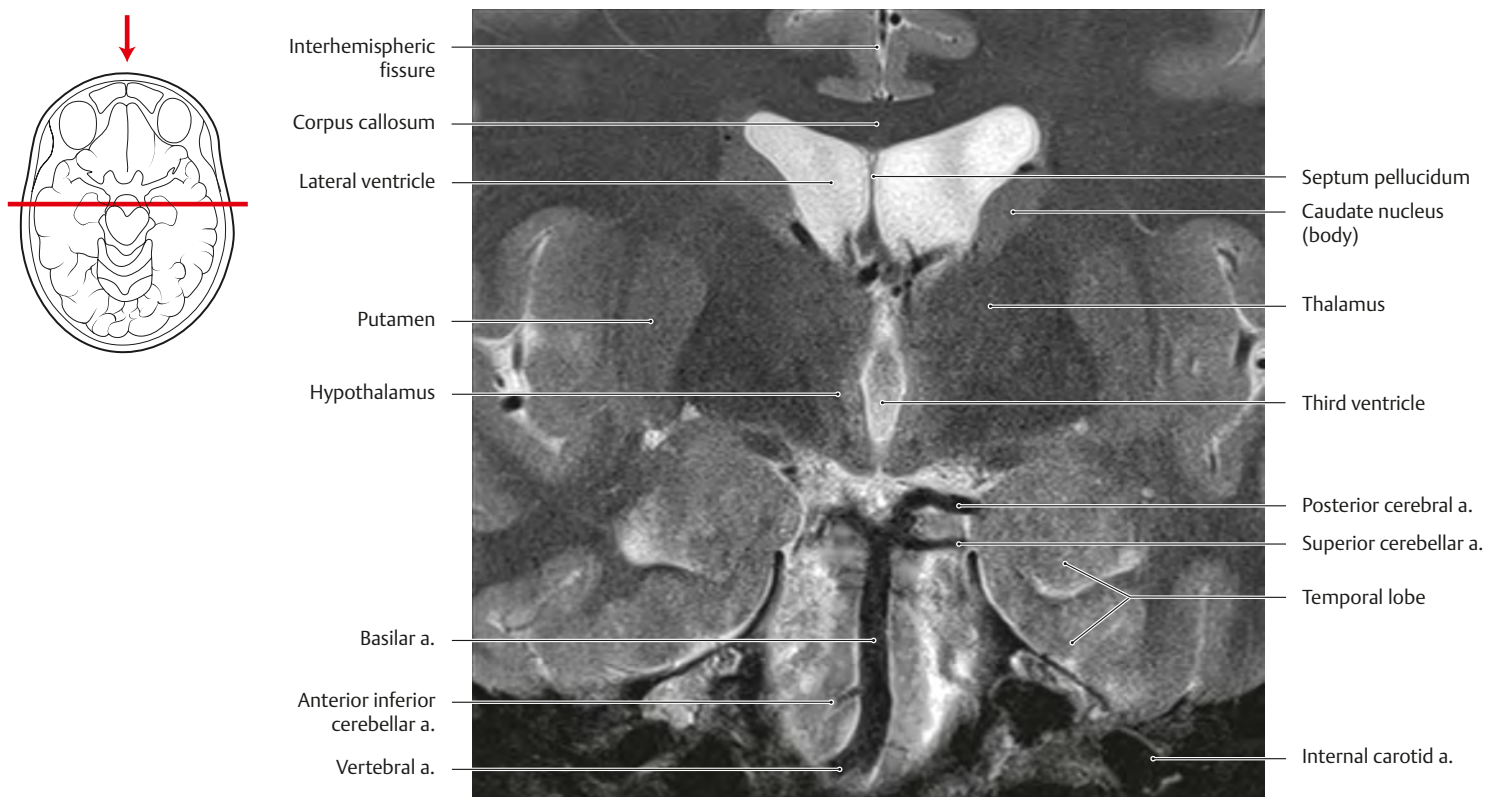
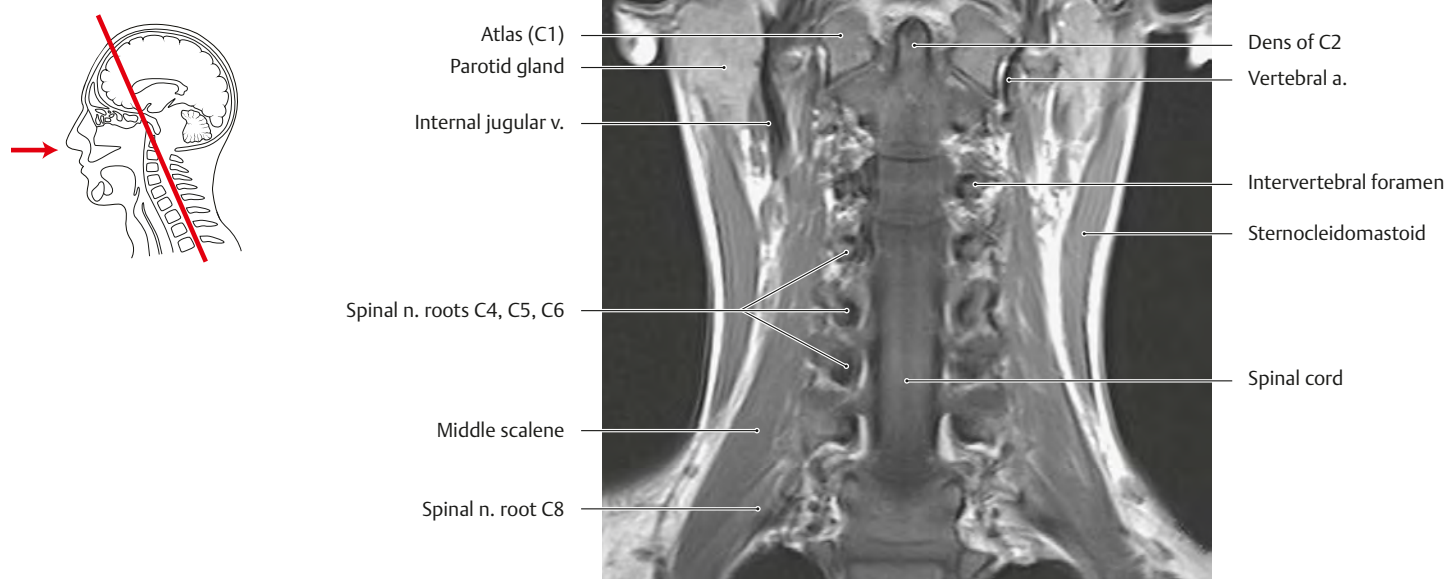


Fig. 51.7 MRI of the brain

Coronal section through the ventricular system. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)

**Fig. 51.8 MRI of the neck**

Coronal section through the cervical spinal cord, anterior view. (Reproduced from Moeller TB, Reif E. Pocket Atlas of Sectional Anatomy, Vol 1, 4th ed. New York, NY: Thieme; 2014.)



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Note: Clinical applications, imaging, sectional anatomy, and surface anatomy are found under these main headings, broken out by region. Italicized page numbers represent clinical applications. Tabular material is indicated by a “t” following the page number.

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